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CHEMISTRY

OF THE

FOUR SEASONS,

Spring, Summer, Autumn, and Winter:

AN ESSAY,

PRINCIPALLY CONCERNING NATURAL PHENOMENA ADMITTING OF INTERPRETATION BY CHEMICAL SCIENCE, AND ILLUSTRATING PASSAGES OF SCRIPTURE.

BY THOMAS GRIFFITHS,

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PREFACE.

"THE Chemistry of the Four Ancient Elements," an Essay founded upon Lectures that I had the high and enviable honor of delivering before the queen, and by her most gracious special permission dedicated to her majesty, had the good fortune to meet with a favorable reception from the public.

I am therefore induced to publish "The Chemistry of the Four Seasons," an Essay founded upon Lectures that I have recently delivered at Scientific Institutions in London and Liverpool, and I hope that it will be found equally worthy of reception.

I have written this Essay, not for the proficient, but for the uninitiated in Chemistry; and I have endeavored to bear in mind that in tracing natural phenomena, "there is not so much required any strength of imagination, or exactness of method, or depth of contemplation, as a sincere hand and faithful eye to examine, and to record the things themselves as they really appear."

It may be safely said, that there is no science more admirably calculated to awaken feelings of interest regarding the wonders of The Creation than that of Experimental Chemistry: the extraordinary disclosures with which it abounds will immediately lead the student to an acknowledgment of the power and goodness of God.

The science of Chemistry will lead the student to "search the Scriptures," and thus to imitate the example of the best and greatest philosophers, for Newton esteemed The Bible "the most authentic of all histories;" Hale said, "none was like unto it for excellent wisdom, learning, and use;" Boyle considered it "a matchless volume, impossible to be too much studied or too highly esteemed;" and Locke pronounced it as "consisting of Truth without any mixture of Error for its matter."

I have humbly endeavored to select a few of the beautiful passages of Holy Writ which refer to Natural Phenomena, and to interpret these through the medium of the science that it is my delight to follow, a science—to employ the words of Davy—"which has its moral and intellectual, as well as its common uses; its object is not only to apply the different substances in nature for the advantages, comfort, and benefit of man, but likewise to set forth that wonderful history of Wisdom and Intelligence which is written in legible characters both in the heavens and on the earth."

To those who have not studied the science of Chemistry, I may say, in the words of the same philosopher, "its beginning is pleasure:" and when they have mastered its rudiments they will find, that "its progress is knowledge;" and lastly, when they have attained its higher combinations and laws, and can venture upon the application of these to the interpretation of natural phenomena, they will confess that "its objects are truth and utility," and eminently calculated to inculcate feelings of thankfulness, gratitude, and reverence, towards The Great Creator, "He that is excellent in power and in judgment."

In this Essay it will be found, that in addition to the interpretation of a few of the phenomena of The Four Seasons, through the medium of Chemistry, I have introduced a variety of other miscellaneous, and I hope both interesting and useful information; all the experimental illustrations are of the simplest character, and do not involve the necessity of costly apparatus; and I have given explicit directions for their performance, so that the student may be certain of their success.

Chemical experiments are often unsuccessful on account of some apparently trifling matters having been neglected; I have endeavored to point out all these, and yet I find, that in the experiment at page 316, I have omitted to state, that in pouring the various solutions through the long funnel, care should be taken to pour them so gently, that *no bubbles of air be carried down the pipe of the funnel*, as these would disturb the levels of the respective liquids; and in removing the funnel, care should be also taken to lift its pipe very slowly, to the level of each liquid, holding it at each for two or three seconds. For the arrangement of this experiment, I am indebted to my friend Mr. T. S. Dick, who affords me his valuable assistance in the Chemical Laboratory at St. Bartholomew's Hospital.

At page 107, line 9 from the bottom, I must request the reader to insert the following paragraph, which I find has been accidentally omitted.

"An equal portion of the clay containing moisture, after being heated to 88 degrees, was exposed in a temperature of 55 degrees; in less than a quarter of an hour it was found to have gained the temperature of the room."

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CHEMISTRY

OF

THE FOUR SEASONS.

INTRODUCTORY.

The Four Seasons present many phenomena which admit of interpretation through the Science of Chemistry.

Some persons imagine that the science of chemistry consists entirely of experiments with furnaces, crucibles, alkalies, acids, salts and metals, which are all more curious than useful, and they will ask—Can the chemist emerge from the narrow precincts of his laboratory, and venture upon the boundless realms of Nature, with explanations concerning the verdure of Spring, the heat of Summer, the harvest of Autumn, and the cold of Winter?

The reply of the chemist is in the affirmative; he can expound such phenomena to a certain extent, for the chief object of chemistry is to ascertain the composition of things, and to determine the laws by which they are governed.

By numerous experiments with furnaces, crucibles, alkalies, acids, salts and metals, the chemist has obtained a key to the vast laboratory of Nature, and, although

standing merely upon the threshold of its newly-opened portal, if he temper his little knowledge with humility, he may witness and understand many of the gigantic and refined operations therein proceeding, under the guiding and protecting hand of Almighty God, for maintaining the regularity and order of the Four Seasons.

The most prominent features of Spring, Summer, Autumn and Winter, may be thus briefly enumerated:—In Spring the earth is covered with verdure; buds and blossoms vary and adorn its surface; soft showers descend; the air is clear; sunshine glads the heavens, and steadily increases in power unto the fervent glow of Summer; then, generally speaking, vegetation has attained its fullness; the earth is crowned with foliage and flowers; the fields are becoming ripe for the sythe and sickle; and soon the sultry noon-tide heat, the refreshing night dew and the lowering thunder-cloud, herald the advent of Autumn;—it comes, laden with purple fruit and golden grain; it yields its bounteous store; it passes,—and then sunshine is pale and languid, winds are bleak and cold, trees become leafless, streams are fast bound with ice, hoar-frost and snow form the winter mantle of the earth.

These Four Seasons, these miraculous changes in the aspect of the globe, these definite periods of Germination, of Growth, of Maturity, and of Repose, familiar to all men, yet unheeded by many, present the votary of chemistry with magnificent illustrations of facts regarding the powers and properties of matter, which he has discovered upon a minor scale by experiments in his laboratory.

To him, who comes with a mind duly prepared and fitted to the business of the interpretation of Nature, in accordance with the axioms of Inductive Philosophy,

the tendency of the science of chemistry is most exalting; at each step it implants a firm belief in the Power, and a perfect reliance upon the Goodness of God, who promised that, "While the earth remaineth, seed-time and harvest, and cold and heat, and summer and winter, and day and night, shall not cease."

The object of this essay is to adduce a few of the principal phenomena of the four seasons, which admit of explanation and illustration through the medium of chemistry; and as it teaches the composition of things, a general statement regarding natural objects and the powers unto which they are subject, will form the remainder of this introductory chapter.

The chemist, by experimenting upon the various solid, liquid, and aëriform matters, presented throughout the creation, discovers that many of them can be divided into two or more substances of distinct and opposite characters, and that these cannot be again divided into others.

Substances that can be divided, analyzed, or simplified, are called Compounds; and such as cannot be so treated, are called Elements.

Fifty-five of these are known, all Ponderable, and subject to the agencies of Light, Heat, and Electricity, which are Imponderable. The ponderable elements are distinguished by the following names;—those marked * are Combustible and non-metallic; those marked † are Incombustible and non-metallic; the others are metallic.

1, Aluminum; 2, Antimony; 3, Arsenicum; 4, Barium; 5, Bismuth; 6*, Boron; 7†, Bromine; 8, Cadmium; 9, Calcium; 10*, Carbon; 11, Cerium; 12†, Chlorine; 13, Chromium; 14, Cobalt; 15, Columbium; 16, Copper; 17†, Fluorine; 18, Glucinum; 19, Gold;

20*, Hydrogen; 21†, Iodine; 22, Iridium; 23, Iron; 24, Lantanum; 25, Lead; 26, Lithium; 27, Magnesium; 28, Manganesium; 29, Mercury; 30, Molybdenum; 31, Nickel; 32†, Nitrogen; 33, Osmium; 34†, Oxygen; 35, Palladium; 36*, Phosphorus; 37, Platinum; 38, Potassium; 39, Rhodium; 40*, Selenium; 41, Silicium; 42, Silver; 43, Sodium; 44, Strontium; 45*, Sulphur; 46, Tellurium; 47, Thorium; 48, Tin; 49, Titanium; 50, Tungstenum; 51, Vanadium; 52, Uranium; 53, Yttrium; 54, Zinc; 55, Zirconium.

Of these elements, the following are the most abundant, and will be most frequently mentioned throughout this inquiry.

I. Combustible and non-metallic,—Carbon, Hydrogen, Phosphorus, and Sulphur.

II. Incombustible and non-metallic,—Chlorine, Nitrogen, and Oxygen.

III. Metallic,—Aluminum, Calcium, Iron, Magnesium, Potassium, Silicium, and Sodium.

The ponderable elements are capable of uniting in various ways to form a great number of compounds; and these compounds in their turn are capable of uniting with each other to form a greater number of complex compounds; and so far as the knowledge of the chemist extends, it leads him to consider that all natural and artificial objects consist of elements, and their combinations and mixtures arranged according to definite laws of weight and measure.

The term Element will occur very frequently during this examination of the principal chemical phenomena of the Four Seasons, and therefore its exact meaning demands explanation at this early stage.

The metal Iron, its tenacity, ductility, and numerous

uses, are familiar to all persons; but the chemist is not satisfied with this mere knowledge of its mechanical properties, he wishes to ascertain the composition of the metal, the things of which it consists; he endeavors to do this by making experiments; he submits iron to every process that he can devise; he alters or disguises its ordinary properties in many curious ways; but at length the metal presents itself in its original state, pure and unharmed by the ordeals through which it has passed, and without yielding the slightest clue regarding its composition.

The chemist depends entirely upon the results of experiments for his knowledge, and in the above instance, he has no alternative but to make a candid confession of his inability to prove of what things Iron consists; and, in accordance with the principles of inductive philosophy, he is obliged to call the metal a Pure, Undecompounded, or Simple substance, a Rudiment, or an Element.

In employing this term he wishes to be distinctly understood, that he does not presume to say that Iron must be absolutely simple or undecomposable, because he is not sufficiently skillful to discover its composition; he merely wishes to express, that he cannot experimentally prove it to contain two or more substances, or, in other words, that he cannot prove it to be a Compound, and in this sense no objection can be made to the term Element.

The substance called Common salt, and its important uses as a preservative of food, are universally known and appreciated; but the chemist wishes to know of what things Common salt consists.

"TRY," is the motto of the laboratory; and accordingly, by trials or experiments, the chemist soon discovers that he can divide Common salt into two new

and distinct substances, one of them a Vapor of a greenish yellow color, and the other a Solid of a silvery lustre; he therefore terms Common salt, a Compound.

The Vapor, he terms Chlorine, in allusion to its peculiar tint; the Solid, Sodium, to denote its identity with that obtained from a plant called the *salsola soda;* and as these are the only two substances obtained by the analysis of Common salt, he terms it Chloride of Sodium, to express its constitution with precision.

But the chemist is now only half satisfied—he has another question ready:—Of what does Chlorine consist, and of what does Sodium consist?

He again appeals to accurate experiment; but he finds that neither Chlorine nor Sodium can be analyzed or simplified, they remain refractory as the metal Iron, they demand to rank with it as Elements, and this position the chemist is reluctantly compelled to grant.

Chalk is another well-known substance:—Of what does it consist? is the question of the chemist: is it an Element like Iron, or is it a Compound like Salt?

The chemist discovers that Chalk will immediately relinquish two new substances, one of them an Invisible Vapor, and the other a White Solid; he therefore terms Chalk a Compound. But the chemist is not contented with this result; he again puts the question,—Are these new substances elements or compounds?

Although one of the substances is an Invisible Vapor, it can be confined, weighed, measured, and experimented upon with the utmost facility; and when the chemist submits it to his most refined operations, it yields two new substances, the one an Invisible Gas, and the other a Black Solid; whilst the analysis of White Solid yields the same Invisible Gas, and a Solid of Silvery splendor.

These new substances now require to be denoted by names; the chemist finds that the Invisible Gas has the power of producing many Acids, and therefore he calls it Oxygen; the Black Solid he discovers to be the pure inflammable principle of Coal, and therefore he calls it Carbon; whilst the Solid of Silvery splendor he discovers to be a constituent of Lime, and therefore he calls it Calcium.

He generally draws upon the rich stores of the Greek and Latin languages for names to denote the various substances that he obtains; and this will be evident upon reference to the list of elements, at pages 19 and 20.

The Invisible Vapor obtained by the chemist during his first experiments upon Chalk, proves to be an Acid compound of Oxygen and Carbon, and to denote this fact, he calls it Carbonic acid; whilst the White Solid substance proves to be an Alkaline compound of Oxygen and Calcium, and therefore he calls it Oxide of calcium, or more familiarly, Lime.

The composition of Chalk, in refined chemical nomenclature, is accordingly expressed by the term Carbonate of oxide of calcium; but the chemist, for brevity, generally calls it Carbonate of lime; it is a compound of two compounds, and these he familiarly calls its Proximate elements, because they immediately come forth, upon the first or proximate analysis, and they will, under certain conditions, immediately unite and reproduce chalk.

On the other hand, Oxygen, Carbon, and Calcium, into which Carbonic acid and Lime are resolvable, do not admit of further analysis or simplification; they are refractory like Iron, Chlorine, and Sodium, and therefore the chemist calls them Ultimate elements, meaning by the term, elements elicited when analysis is carried to its utmost *possible* extent.

The union of two or more Ultimate elements constitutes a Primary combination; and that of two or more Proximate elements, a Secondary combination; and as the chemist, throughout all his researches, is guided by a constant appeal to a just and delicate balance, he discovers that each kind of combination is governed by a definite weight.

For example,—if he experiment upon 1000 parts by weight of Chloride of sodium, he will invariably obtain 600 parts of Chlorine and 400 parts of Sodium; if upon 1000 parts of Carbonate of lime, he will first obtain 440 parts of Carbonic acid, and 560 parts of Lime; if he pursue the ultimate analysis of these compounds, he will obtain from this quantity of Carbonic acid 320 parts of Oxygen, and 120 parts of Carbon; and from the Lime, 160 parts of Oxygen, and 400 parts of Calcium.

If the chemist, by well-known agents, excite the above substances to combine as Primary, or Secondary compounds, they will only do so in such weights; he has no power of forcing them to combine according to his caprice; a grand and immutable law of Definite weight presides over every analytical and synthetical operation.

Chemistry, thus tending to the discovery of the elements of things, and of the laws by which they are controlled, presents its votary with powerful illustrations of the Truth, that "a just weight and measure are the Lord's;" that "a just weight is His delight;" that "He comprehended the dust of the earth in a measure, and weighed the mountains in scales, and the hills in a balance."

The chemist endeavors to act as the humble and faithful interpreter of the wonders of the Creation, and everywhere discovers proofs of the power and goodness of God: what a glorious contrast does this exalted occu-

pation present to the sordid pursuits of the darker ages, when the transmutation of metals, and the production of an elixir of immortality, formed the vain and presumptuous hopes of the experimenter!

Throughout the Four Seasons, it must be obvious that Air, Water, Earth, and Heat, are ever active and important agents, and therefore a general account of their chemical habitudes demands a place in these introductory pages, to facilitate our future proceedings.

The science of chemistry is founded upon the laborious yet certain practice of EXPERIMENT, and by its aid the Air, or Atmosphere, is proved to consist chiefly of two elementary gases, named Oxygen and Nitrogen; they are strongly opposed in their chemical characters, for the former will support life, and flame, for a time, but the latter will destroy both instantaneously.

The chemist can combine Oxygen and Nitrogen, in definite proportions, by weight, and produce Five compounds, as shown in the following statement:

I. Oxygen, 3640 + Nitrogen, 6360 = 10000 Nitrous oxide.
II. Oxygen, 5333 + Nitrogen, 4667 = 10000 Nitric oxide.
III. Oxygen, 6320 + Nitrogen, 3680 = 10000 Hyponitrous acid.
IV. Oxygen, 6960 + Nitrogen, 3040 = 10000 Nitrous acid.
V. Oxygen, 7410 + Nitrogen, 2590 = 10000 Nitric acid.

I. Is an invisible vapor, called Nitrous oxide, to denote that it is not acid.

II. Is an invisible gas, called Nitric oxide, to denote that it is not acid; and by the termination *ic*, that it contains more oxygen than the former.

III. Is an acid liquid, called Hyponitrous acid, to denote that it is intermediate with Nitric oxide and Nitrous acid, and below the latter in its proportion of oxygen.

IV. Is an acid vapor called Nitrous acid, to denote that it contains less oxygen than Nitric acid.

V. Is called Nitric acid, to denote its large amount of oxygen; the chemist has not determined if nitric acid be solid, liquid, gas, or vapor, but he is certain of its composition.

These five compounds are deadly poisons to animated beings, and yet they contain the elements of Air, which is the pabulum of life,—how can this be? The chemist replies that, to constitute Air, these elements are not combined, they are only mixed, and very nearly in the following weights:—

Oxygen, 2300 + Nitrogen, 7700 = 10000 Air.

These elements are rendered incapable of combining under all ordinary circumstances, they remain intimately and uniformly mixed to constitute the first, and the last food of life.

But when the lightning goes forth, as the terrible display of natural electricity in the thunder storm, the chemist discovers that the elements of the air in the immediate passage of the flash, are suddenly excited to combine and produce the poison called nitric acid; but this effect is miracuously restrained by the hand of Providence, and not permitted to ensue throughout the entire volume of the air, or inevitable would be the destruction of every living thing; and the relatively minute portion of poison thus formed during a long protracted discharge of lightning, is soon infinitesimally diffused throughout the untainted volume of air, or absorbed by the waters, or neutralized by the earth, and thus deprived of virulence.

The animated creation is thus miraculously preserved amidst the elements of destruction; true indeed is the solemn warning, that "in the midst of life we are in death."

These extraordinary elements, Oxygen and Nitrogen, form the chief volume of the Atmosphere during all the vicissitudes of the Four Seasons; but a rigid analysis likewise proves the simultaneous existence of small quantities of two compounds, named Carbonic acid, and Water. Reference has been made to the composition of Carbonic acid, and when obtained from the air or other sources, in a pure or insulated state, it is fatal to animal and vegetable life, and is materially heavier than either Oxygen or Nitrogen; but as mingled with these elements, and the vapor of water, to constitute Air, it has a beneficial influence, and never subsides as a distinct mephitic stratum.

The chemist discovers that Water is a compound of Oxygen and Hydrogen, an elementary gas thus named in allusion to its producing that substance; the following are the weights in which these elements combine:—

Oxygen, 8890 + Hydrogen, 1110 = 10000 Water.

It does not exist in the mixture of Oxygen, Nitrogen, and Carbonic acid, as Liquid water, but as Vapor of water, produced by the all-prevailing agency of solar heat; thus it is wafted over the surface of the globe, until local changes of temperature cause its condensation, and fall, as rain or snow, and other well-known forms, according to the season.

The result obtained by a minute analysis of Air, presents the following weights of its elementary and compound constituents.

Nitrogen - - - - -	7555
Oxygen - - - - -	2332
Carbonic acid - - - -	10
Aqueous vapor - - -	103
	10000

This wondrous medium, or atmosphere, containing the elements of life and of destruction, enfolds the earth as a mantle; and although the chemist cannot experimentally determine its limit, he can determine its total weight, and is perfectly astounded at its immensity; it is expressed by the sum of Five quatrillions, two hundred and eighty-seven trillions, three hundred and fifty billions of TONS!

The accompanying statement will show the relative proportions by weight, in which the elementary and compound constituents of Air are blended, to produce this gigantic sum total.

Nitrogen - - -	3.994.592.925.000.000
Oxygen - - -	1.233.010.020.000.000
Carbonic acid - -	5.287.305.000.000
Aqueous vapor -	54.459.705.000.000
TONS	5.287.350.000.000.000

Both the chemist and the physiologist concur in stating, from the results of numerous experiments, that no elementary gas, no compound gas, no elementary vapor, no compound vapor, no other mixture or combination of elementary or compound gases, or of elementary or compound vapors, can support the respiratory functions of the animated creation like Atmospheric air; and its ultimate analysis presents Four elements, namely, Oxygen, Nitrogen, Carbon, and Hydrogen.

Water is presented throughout nature in lavish abundance; it occupies more than three-fourths of the superficies of the globe; but philosophers cannot determine the total weight of this enormous bulk of water, as they can that of the atmosphere.

The chemist discovers that water, as it falls from the clouds, invariably contains air, and sometimes a compound of hydrogen and nitrogen, called ammonia, to which much of its fertilizing power may be referred: he further discovers that the water of springs, brooks, and rivers, always contains portions of earthy and saline compounds, particularly common-salt, although not sufficient to destroy its freshness, and unfit it for the beverage of man and animals.

The chemist discovers that the water of springs, in certain localities, is so impregnated with gaseous, earthy, and metallic compounds, as to be unfit for constant use as a beverage, yet occasionally taken, it exerts considerable influence in palliating or removing some forms of disease; and pursuing his investigations regarding the water of the ocean, which, when drank, soon causes delirium and death, he discovers it to derive its strong saline taste from a proportion of common-salt, far exceeding that in ordinary spring, brook, or river water; and its bitter taste, from an inferior proportion of compounds of lime and magnesia.

But during all experiments and researches upon water, the chemist cannot find a solitary instance of its occurring in nature absolutely pure, or solely consistent of the elements, Oxygen and Hydrogen; he can render it so, artificially, and then he finds it is perfectly unfit for the beverage of man and animals; he has, therefore, reason to admire the wonderful provision of the Creator,

in ordaining water to contain principles, in addition to its own elements, which are indispensable to the support of vitality.

The solid parts of the globe, which are popularly called the Earths, as, for example, Lime, Sand, Clay, and Magnesia, are, in fact, compounds of Oxygen, with the metals, Calcium, Silicium, Aluminum, and Magnesium; they are rusts of these metals, or metallic oxides, and as such they are styled in refined chemical language, but they will be spoken of as Earths in this inquiry, and the following statement will show their composition.

I. Oxygen, 286 + Calcium, 714 = 1000 Lime.
II. Oxygen, 500 + Silicium, 500 = 1000 Sand or Silica.
III. Oxygen, 480 + Aluminum, 520 = 1000 Clay or Alumina.
IV. Oxygen, 400 + Magnesium, 600 = 1000 Magnesia.

These earths are sometimes found very pure, but more frequently mingled together, or combined with other metallic oxides, as, for example, those of iron and potassium: thus common clay contains a large portion of alumina, to which its tenacity and plasticity with water are entirely referable; but it also contains portions of silicia, and oxide of iron, which cause its grittiness and color; and lastly, oxide of potassium or potash, which renders it fertile for the growth of corn.

The chemist discovers that the earths are likewise presented by nature, in combination with Acids containing the inflammable elements, Carbon, Sulphur, and Phosphorus. These are respectively called Carbonic, Sulphuric, and Phosphoric acids, and their combinations with the earths are called Carbonates, Sulphates, and Phosphates.

Thus, for example, Chalk, Limestone, and Marble, are

Carbonates of Lime; Gypsum and Alabaster are Sulphates of lime; and Bone-earth contains Phosphate of lime and Phosphate of magnesia.

The earths, when absolutely pure, are solid, incombustible, infusible, excepting in the most intense degree of artificial heat that can be commanded; they are insoluble in water, with the exception of lime.

When the earths naturally occur in various states of purity, they have the foregoing characters in a very eminent degree; their natural and artificial compounds with each other, with several metallic oxides, and with the above acids, in the generality of instances are similarly characterized.

A general notion of the manner in which earths, earthy and saline compounds, organic matters, and water, are mingled together to constitute a soil, may be gained from the following statement, which supposes that 1000 parts by weight of a soil, have been submitted to proximate analysis.

1000 Parts of Soil.

	Parts.
Large loose stones and silicious gravel	143
Fine silicious sand	572
Aluminous earth	75
Carbonate of Lime	47.5
Carbonate of Magnesia	7.5
Sulphate of Lime	5
Oxide of iron	12.5
Salts of sodium and potassium	10
Phosphate of Lime	2.5
Vegetable and animal manure	72.5
Water	52.5
	1000.0

The more particular examination of soils, as regards

their relative fertility, will be given hereafter; and it is by a correct knowledge of the nature of the pure earths, and their compounds, and various mixtures with organic and inorganic matters, that the chemist is enabled to afford valuable information to the agriculturist, and thus assist him materially in augmenting the produce of the autumnal harvest.

It is true that every man can cause ground to bear corn, yet it will only grow in abundance, and of the best quality, where sown after rational principles, and the labors of the agriculturist are profitable and useful in proportion as he is acquainted with the rudiments of chemical science.

Air, water, and earths, are inorganic substances; they neither grow nor are they reproduced; they have no period that may be called their perfection; but Seeds, upon which the hopes of the agriculturist are founded, are Organic bodies, produced by the powers of vitality; they have periods of growth, maturity, death, and decay.

Can the chemist extend his analytical researches to seeds, and other organic bodies, and ascertain their elements, as he can those of air, water, earths, and inorganic matter? He can: all organic bodies admit of analysis, and with reason it might be imagined, that hundreds of elements would be elicited by such an extensive investigation of the diversified array of animated nature. How different is the fact obtained by experiment, for it teaches the chemist that only Four elements enter into the essential constitution of all organic productions!

These Four elements are Oxygen, Nitrogen, Carbon, and Hydrogen, or the ultimate elements of the atmosphere. This statement may appear incredible, but it is

an experimental fact, and, moreover, some vegetable and animal structures do not even contain nitrogen.

This discovery presents a magnificent illustration of the power and goodness of God, who created these elements, and controls their arrangement by definite and unerring laws, into countless forms of beauty and utility, for the adornment and enrichment of the earth.

It must be remembered that such combinations are under the influence of the incomprehensible agency of vitality, and towards it man can make no approaches.

As a chemist, he is permitted to analyze the air, the water, the earths, and to recompose nearly all, in the same weights of their constituents, as those in which they were presented for his examination; he is likewise permitted to analyze all organic bodies, and to obtain their three or four elements, in weights, the sum total of which exactly equals the original weight of the body subjected to experiment; but he is not permitted to exercise synthesis. He may place these elements together, in every possible manner that human skill can suggest, employ upon them the most powerful exciting agencies at his command: they will neither combine to produce the original body, nor the slightest resemblance of an organized body.

The chemist thus meets with an impassable barrier to synthetical operations, and upon all occasions when he encounters recondite matters, which do not admit of elucidation by his own limited and insignificant acquirements, he does not perplex his mind with presumptuous efforts to tear the veil of mystery that he cannot raise, but humbly yields submission to the Truth—"that the things which are impossible with man, are possible with God."

"There is no part of chemistry which abounds in more extraordinary disclosures than that connected with the composition and properties of organic products. It teaches us that, infinitely diversified as they apparently are, none of them seem essentially to contain or include more than three or four elementary substances."

"Fifty-five elements are presented to us by nature: of these, only four are employed in the elaboration of all the wonderful creations of living matter."

"Flowers and perfumes, leaves and wood, food and poisons,—flesh, fat, hair, feathers,—when the chemist comes to look at all these, he finds that such wonderful diversity is the result, not of the employment of a multiplicity of elements, but of the combination of a very few, in varied proportions, and under the influence of vital agency."

To render this extraordinary fact still more impressive, a tabular statement is here subjoined of the analysis of ten proximate principles. Gum, Sugar, Starch, Lignin or woody fibre, Wax and Gluten, are of vegetable origin; Gelatin, Albumen, Fibrin, and Fat, are of animal origin.

	Gum.	Sugar.	Starch.	Lignin.	Wax.
Carbon	414	421	428	500	806
Hydrogen	65	64	63	56	114
Oxygen	521	515	509	444	80
	1000	1000	1000	1000	1000

	Gluten.	Gelatin.	Albumen.	Fibrin.	Fat.
Carbon	557	483	516	520	790
Hydrogen	78	80	75	72	118
Oxygen	220	276	259	250	92
Nitrogen	145	161	150	158	000
	1000	1000	1000	1000	1000

From this statement, we discover that the proximate principles of Vegetables, with the exception of Gluten, contain but Three elements, and that those of Animals, with the exception of Fat, contain Four; and whilst its composition is closely analogous to that of most vegetable principles, that of gluten approximates to the composition of most animal principles. The important consequences of these discoveries will become apparent at a future stage of our inquiry.

All ponderable elements, and the host of natural and artificial compounds in which they exist, are subject to the imponderable agencies of Light, Heat, and Electricity, which modify and control all chemical changes, but more particularly those of organic productions.

The chemist is totally ignorant of the ultimate nature of these imponderable or ethereal matters; he cannot experiment with them as with solids, liquids, gases, or vapors; he is only acquainted with them when acting upon such ponderable forms.

Solar light enters the confines of the atmosphere, permeates its transparent volume with incredible velocity, and illuminates the solid opaque earth.

Such light is absolutely necessary for the welfare of the animal and vegetable creation; its presence stimulates a healthy action of their vital functions, and causes the elaboration of elements that enter into the constitution of organized structures; whilst, in the prolonged absence of light, morbid and fatal changes will generally ensue.

The power and goodness of God are magnificently displayed in solar light, it being, not of one color, but of seven colors, a fact that we behold with admiration

and gratitude, in the stupendous arch of varied light, which so frequently spans the heavens as the rainbow.

"Look upon the rainbow, and praise Him that made it; very beautiful it is in the brightness thereof; it compasseth the heavens about with a glorious circle, and the hands of the Most High have bended it."

The very limited extent to which scientific inquirers can reason and experiment upon an element so inconcievably attenuated as solar light, leads them to consider that the bow may be caused by the colored refraction of light by drops of rain, for it is found that when the solar rays are caused to impinge upon watery spray, similar colors to those of the rainbow appear, although microscopic in comparison with its gigantic span.

These colors likewise appear when the solar beam is refracted by the denser solid medium of flint glass; a triangular prism of this invaluable compound probably elicits the phenomenon in the greatest perfection and beauty attainable by human skill; hence the term Prismatic colors applied to the Red, Orange, Yellow, Green, Blue, Indigo, and Violet, rays of light which constitute the spectrum.

When these Seven colored rays are collected to a focus, by a glass lens, they coalesce into colorless light, and are therefore presumed to constitute such ethereal agent.

The chemist discovers that the colored rays are possessed of different chemical powers; that the red have the highest, and the violet the lowest temperature; that the former have but little, and, in some instances, no tendency to promote chemical changes, whilst the latter are most powerful excitants of such phenomena.

If solar light were of one color, or mono-chromatic,

all terrestrial objects would appear of such color, or, if incapable of reflecting it, they would appear black; we should not be charmed with the varied and gorgeous hues of the creation; but light being seven-colored, or chromatic, and the surfaces of objects being differently constituted, both physically and chemically, they are capable of reflecting, in some cases, all the rays, and thus of appearing white; and, in other cases, of absorbing them all, and thus of appearing black; but more generally of reflecting certain simple rays, or mixtures of rays, in preference to others, and of thus impressing the eye with numerous shades of color.

Light is accompanied by heat during its swift passage from the sun to the earth, but heat is an imponderable element, and therefore the chemist is obliged to rest content with examining its effects upon terrestrial objects; and although he can artificially elicit heat by various experiments, he is even then ignorant of its nature.

"In all our excursions over the surface of the globe, innumerable objects excite our admiration, and contribute to inspire delight; but whether our graitude is awakened by the verdure of the earth, the lustre of the waters, or the freshness of the air, it is to the beneficial agency of heat, under Providence, that we are indebted for them all.

"Without the presence and effects of heat, the earth would be an impenetrable rock, incapable of supporting animal or vegetable life; the waters would be for ever deprived of their fluidity and motion; and the air of its elasticity and utility together.

"Heat animates, invigorates, and beautifies all nature; its influence is absolutely necessary to enable plants to grow, put forth their flowers, and perfect their fruit;—it

is closely connected with the powers of life, since animated beings lose their vitality when heat is withdrawn.

"Such is the universal influence of this powerful agent in the kingdoms of nature; nor is this influence diminished in the provinces of art; it is with the aid of heat that rocks are rent, and the hidden treasures of the earth obtained; matter is modified in countless ways by its agency, and rendered subservient to the uses of man; furnishing him with useful and appropriate implements, warm and ornamental clothing, wholesome and delicious food, needful and effectual shelter."

Solar heat, and artificial heat, are indeed powerful agents; the former most particularly, as connected with the varied phenomena of the Four Seasons, and, with one exception, to be reserved for minute consideration hereafter; all substances enlarge in bulk when heated, and contract when cooled.

These temporary expansions by heat, and contractions by cold, are but small in the generality of closely-compacted solids, great in mobile liquids, and greatest in attenuated gases and vapors.

Some substances, especially the metals and their ores, have the power of conducting heat with great facility throughout their entire mass, so that it matters not where heat be applied, they will in due time be equally elevated in temperature.

Other substances, especially the earths, and their compounds, generally absorb heat rapidly upon their surfaces, and only conduct it very slowly and imperfectly throughout their mass, therefore heat chiefly remains upon the part to which it is originally applied.

Lastly, some substances, especially air and water, will not admit of being heated by conduction.

The chemist accordingly classes the foregoing substances as conductors, imperfect conductors, and non-conductors of heat; and he has reason to admire and appreciate the beneficial results that ensue from their several habitudes with this agent. The transparent atmosphere is so wonderfully constituted, as to allow the rays of the sun to pass through it, without absorbing their heat; but upon reaching the opaque surface of the solid earth, it immediately absorbs heat, and becomes elevated in temperature; then the air incumbent upon it obtains heat by contact, and is thus rendered lighter, volume for volume, than it was; it rises, and its place is immediately occupied by another and colder stratum of air; this becomes heated and lighter, and in its turn rises, whilst colder air falls, and thus by ascending and descending, or convective currents, the atmosphere becomes heated from the earth, and not by direct conduction from the sun.

Thus winds are produced by the continued motion of cold air to supply the place of that which ascends in a heated state.

Transparent water is heated by the warm air that blows over its surface, and not by direct conduction of heat from the sun; but these matters will be particularly explained in their proper season: it may, however, be remarked, that if earth, air, and water, were conductors of heat, the animated creation could not exist; the sun would immediately heat the earth intensely; the water would wholly disappear; the air, instead of being a temperate mantle, would become a scorching shroud, or, in the more emphatic language of Scripture, "the heaven would be as iron, and the earth as brass."

Electricity is the third imponderable element of whose

proceed to examine the conditions under which water accumulates in the atmosphere, to form the showers of Spring, and its fertilizing agency even when it does not so descend upon the earth; the action of heat and cold upon the atmosphere will then claim our notice, and the changes which it sustains by respiration, germination, and combustion; we shall then pass on to examine some of the habitudes of the earth, in retaining heat, and the beneficial results which ensue from these; lastly, resuming the examination of vegetable growth, a few of the peculiar functions of plants will occupy our attention, as preparatory to others which will present themselves in the ensuing season of Summer.

First, as regards the Chemical phenomena, attendant upon the germination of seeds, and the growth of plants.

If we examine a seed, and for our general purpose no better can be selected than a garden bean, we find that its external membrane, or covering, is easily removed, and then it may be divided into two distinct portions, which are called *Cotyledons;* these enclose the *germ*, or *embryo*, whose largest part, or that most embedded in the Cotyledons, is called the *plumula*, and its smallest part, or that almost escaping from them, the *radicle.*

Fig. 1.

Upon tasting the cotyledons, we find them amylaceous, and insipid, for chemical analysis proves them to consist chiefly of a proximate vegetable principle called Starch,

a compound of Carbon, Oxygen, and Hydrogen, wonderfully elaborated by Nature into the form of the seed, and having no tendency to change under ordinary circumstances during the lapse of ages.

If we cast a seed of this kind into the earth,—no matter in what position,—and carefully examine it from day to day, we find that it sustains changes which are not presented by an equal bulk of inorganic matter similarly situated.

The seed swells considerably; its external membrane bursts, an upward and a downward shoot protrude from

Fig. 2.

the cotyledons, the former being an enlargement of the plumula, the latter that of the radicle.

In a few days the plumula will emerge from the soil, whilst the radicle penetrates much lower than the original position of the seed; and then it will be found, upon tasting the cotyledons, that they are no longer amylaceous or insipid, but sweet and mucilaginous, because the proximate element called Starch has arranged its elements, Carbon, Oxygen, and Hydrogen, to constitute two new proximate elements, called Sugar, and Gum.

At the same time we shall observe, that numerous vessels are disposed throughout the coytledons, for the purpose, as it is presumed, of conveying these principles as generous nutriment to the newly-born plant, until it has acquired sufficient maturity to procure other support

for its welfare from the air and the earth; and when this happens, the saccharine and mucilaginous principles entirely disappear from the cotyledons; they decay, and allow the plant to remain entirely dependent upon the leaves which are developed in the plumula, and the fibres of the radicle for its future sustenance.

Fig. 3.

The silent and miraculous phenomenon of Germination will only ensue under certain conditions; in the first place darkness is required, and it is ensured by the opacity of the soil in which the seed is cast; yet when the germ has acquired sufficient strength to burst, and rise as the plumula from its terrestrial prison, and to meet the air, light immediately becomes essential for its health and growth towards maturity. In the second place, the seed requires a due temperature, which must always exceed 32 degrees, and never exceed 100 degrees of Fahrenheit's thermometric scale; it also demands a liberal supply of water, either in the liquid or the vaporous state, and perfect access of air.

These agents, ponderable and imponderable, must be admitted, not singly, but conjointly;—for example, plant the seed in the earth, allow it the free access of water and air, and it will not germinate if the temperature of the earth be reduced to 32 degrees; neither will it germinate between such temperature and 100 degrees, though liberally supplied with water if the access of the air be prevented.

Bury the seed deep in the earth, and so situate, it

will neither germinate nor decay; it will remain unchanged or dormant; but remove it near the surface, so that the porosity of the soil may admit of the just and naturally combined agencies of air, water, and heat, it will quickly start into life, and its emerging plumula become verdant under the influence of solar light.

Knowledge of the above fact enables the Chemist to explain why the surface of barren earth, newly turned or excavated, so frequently becomes covered with luxuriant vegetation; seeds were buried deep in the earth, probably by natural convulsions in past ages, and thus rendered incapable of undergoing the changes requisite for their germination to ensue; but these are immediately excited when the combined influence of the foregoing agents is admitted.

Common experience teaches us that seeds must be sown at the depth of a few inches in the earth, or they will never put forth shoots above its surface; the chemical reason of this practice is, that they may gain a requisite supply of air, water, and heat through its pores.

Thus loamy and calcareous soils, being porous and light, admit air, water, and heat to seeds, and are generally fertile; whilst clay-land, being compact and adhesive, opposes the admission of such agents, and frequently is not so productive; indeed it often retains water in such excess that seeds become rotten and worthless.

So far as the Chemist can ascertain by experiment, it appears to be chiefly by the absorption of water in properly tilled soils, that the cotyledons of a seed are enabled to increase in bulk, to put forth a plumula and a radicle, and to transmute their original constituent starch

into the new principles of sugar and gum: but of this matter hereafter. Let us now inquire how the genial showers of spring are received by the earth, to promote the germination of seeds and the growth of plants, that clothe its surface with verdure.

Water is received by the earth in consequence of a attractive force existing between liquids and porou solids generally; this force is denoted by the ter Capillary Attraction; it is a most important and eve active agent throughout nature.

Capillary attraction admits of illustration by the fol lowing simple experiments, and after performing the they will be found explanatory of the manner in which water is received and retained by the earth.

Take a piece of cane, about an inch and a half long, having its ends cut perfectly flat and smooth, hold it perpendicularly, and place a drop of water upon the upper end; the drop will soon vanish, and so will another, and another, until the lower end of the cane becomes wetted; the water will not suddenly run through the pores of the cane, which are nearly as fine as hairs; they retain it in opposition to the attraction of gravitation, and this retention is called capillary attraction of the liquid, from the Latin word *capillus*.

Fig. 4.

This capillary attraction of the fine pores of the cane will also raise water in opposition to the attraction of gravitation, which would otherwise cause its fall.

Take another piece of cane, similar in dimensions to that employed in the last experiment, place one end just below the surface of water, and, in the course of a few seconds the upper end will become wetted.

In this instance capillary attraction is again superior to the attraction of gravitation, or the water would not rise above its ordinary level; but still it is mere mechanical attraction, unaccompanied by chemical change; the cane and the water are both of the same composition as they were at the outset of the experiment.

Sponge is a very porous substance, and when thrown into water it does not disappear or dissolve, because the water has no chemical attraction for the particles of which it is composed; but it will mechanically attract and retain a very large quantity of the liquid, because sponge may be considered as consisting of myriads of small tubes interwoven or interlaced in all directions, and exerting capillary attraction for the water, as energetically as did the perfectly straight tubes or pores of the cane.

Take another example, bearing yet more strongly upon the rationale of capillary attraction in nature:—A heap of sand consists of countless solid atoms of silica, not in absolute contact, as its examination by a magnifier will immediately prove, but separated by interstices; or, in other words, a heap of sand is full of capillary pores, and these will become filled upon the addition of water.

To render this more intelligible, or to represent, upon a magnified scale, the grains of sand and their inter-

Fig. 5.

stices, a large glass may be filled with marbles; whilst to denote the water (whose liquid particles, philosophers have likewise every reason to believe, are not in absolute contact) a small glass may be filled with rape-seed; this, when poured among the marbles, will fill their interstices, as the water did those of the sand.

Place a shell or a piece of tile over the aperture in the lower part of a flower-pot, fill it with dry sand, then pour water upon its surface, and remark the large quantity that may be added before any portion flows from the aperture; when it does so, the capillary pores of the sand are saturated, and the excess of water passes through, in obedience to the attraction of gravitation.

When the mould in a flower-pot becomes excessively dry, we know that a great quantity of water may be poured upon its surface before any escapes from the aperture into the saucer beneath: this depends upon the capillary attraction of the pores of the mould, as just exemplified in the case of sand.

Suppose the saucer become filled with water, we find it soon vanish if the plant in the flower-pot be in full vigor.

Why does the water vanish? Not by drying away,—in the common meaning of the term,—but in consequence of being attracted upwards—as was the water by the porous cane—to supply the roots of the plant, in which capillary vessels exist, and these transfer it to the stem, leaves, and flowers, from whose surfaces it ultimately dries away or evaporates; therefore, in place of watering the surface of the mould, we very frequently pour water into the saucer, and depend, as now shown, upon capillary attraction for the rise of the liquid to maintain the life of the plant.

A porous substance has the power of raising water to a very remarkable extent, as may be proved by the following simple experiment.

Select a lump of common salt, cut it with a saw into a regular shape, about six inches long, two inches broad, and one inch thick, then set it to dry perfectly before a fire. Fill a shallow plate with water, containing sufficient red ink to impart a deep tint, and when the lump of salt is dry, place it upright in the plate, as here shown.

Fig. 6.

The salt, though apparently solid, is in fact full of capillary pores; these will instantly attract the reddened water, and the salt will become powerfully stained to a very considerable height. The red ink is only added to render the result more striking than it would be if water alone were employed.

In the course of a few seconds the salt will fall, on account of the chemical solvent power of the water undermining its lower part, or, in other words, on account of the solid particles of the salt being now received by the interstices between the individual atoms of the water, which action is regarded as solution; but it does not necessarily follow that a substance capable of exerting capillary attraction should thus be soluble. A lump of porous sandstone, for example, similarly placed, will at-

tract water, but will not fall, even when perfectly saturated, because it is an insoluble substance.

In nature, it frequently happens that capillary attraction and chemical solution act simultaneously, and produce highly important results in conveying liquid manure to the roots of plants, by which their growth is wonderfully promoted. Vegetation on the margin of a brook, or pond, is generally more luxuriant than on the soil a few yards distant, because the porous earth of the bank attracts water abundantly, and retains it very forcibly even in time of drought.

Whilst upon this subject, it may be stated, that much of the dampness in the walls of buildings depends upon the porous brick or stone-work of the foundations attracting water from the earth, and it frequently causes great damage and inconvenience.

Oolite, or Bath-stone, as it is popularly called, is much employed in the decorative architecture of interiors, on account of the extreme facility with which it may be sawn and wrought into the most delicate tracery, and in such situations, if protected from damp, it will remain unimpaired for ages, as exemplified in many abbeys and cathedrals.

Requiring little labor from the masons, and producing a most beautiful effect, architects have been occasionally tempted to employ oolite for external work; but it is not durable, because water is rapidly absorbed by capillary attraction, and this extraordinary liquid, by undergoing expansions and contractions during the changes of atmospheric temperature, and more particularly expansion upon freezing, flakes of the stones are violently detached, and the original sharp outline of the work broken down. This action silently, though cer-

tainly, continued for years, the sculptured work becomes undistinguishable.

Turning from the works of Art to those of Nature, as more particularly connected with this inquiry regarding the principal chemical phenomena of the Four Seasons, we discover capillary attraction to be a most active agent in retaining and administering a proper supply of water to the vegetation upon certain soils and rocks.

In sandstone and limestone districts, which particularly abound in England, the absorption and retention of water for the support of vegetation are very remarkable; we may see luxuriant plants, nay, even forest trees, flourishing upon both rocks, the sandstone being porous, the limestone full of cracks or fissures, all readily imbibing water from the heavens, retaining or yielding it in proportion as it is demanded, for the sustenance of vegetable life.

It is no uncommon thing in such districts to see plants and trees sending forth their roots into such cracks and fissures in search of moisture, and occasionally, when these cannot yield sufficient, the root will travel completely down the external surface of the rocks to draw a supply from the more humid soil at their base.

Different is the case when compact, glassy granite is the prevailing rock of the country; it is incapable of exerting capillary attraction for water; it cannot provide itself with vegetable clothing, and therefore stands forth in bare and gaunt outline.

When the careful agriculturist observes a particular district, in which vegetation naturally thrives, it becomes a matter of importance with him to ascertain the cause of such fertility; and upon application to the chemist, the desired information can be obtained.

He can determine the average quantity of water absorbed and retained by the soil under ordinary vicissitudes of the atmosphere; he can determine the nature of its components, the exact proportions of sand, clay, calcareous compounds, organic, and other matters, that it contains, and can frequently artificially compose a soil equally fertile with that naturally found, or he can render it still more productive by the judicious and well-timed application of various organic and inorganic matters as manures.

Chemistry thus becomes directly applicable to agriculture, and many agriculturists have embraced its study, and by obtaining a sound knowledge of its rudiments, have been enabled to ameliorate the condition of soils upon rational principles.

"Plants, being possessed of no locomotive powers, can grow only in places where they are supplied with food; and the soil is necessary to their existence, both in affording them nourishment, and enabling them to fix themselves in such a manner as to obey those mechanical laws by which their radicles are kept below the surface, and their leaves exposed to the free atmosphere."

"As the systems of roots, branches, and leaves are very different in different vegetables, so they flourish in most different soils; the plants that have bulbous roots require a looser and a lighter soil than such as have fibrous roots; and the plants possessing only short fibrous radicles, demand a firmer soil than such as have tap-roots, or extensive lateral roots."

The manner in which the chemist proceeds to analyze soils, cannot be particularly described in this examination of the Chemical Phenomena of the Four Seasons, because it involves several agents whose action would not

be readily understood; it mainly depends upon presenting to the soil some element or compound that will attract away one of its components in preference to another. This may be tangibly illustrated, in the first place, as follows.

Mix a heap of iron filings with an equal heap of sand; —let these represent two distinct components of a soil, and suppose that their ready separation is required.

If a strong magnet be thrust into the mixture, it will only attract the iron filings, and effectually separate them from the grains of sand; the mixture is thus immediately analyzed.

Mix common salt and sand;—it would be very difficult, almost impossible, to separate, or to pick out, their individual grains, even if the eye were aided by a magnifier; and, as mechanical means fail, chemical means must be tried.

Experience teaches us that salt will dissolve in water, and that sand will not: therefore if water be added to this mixture, and agitated, and poured off, and more water added and agitated, and again poured off, until it has no saline taste, the sand will remain, and by placing the solution of the salt in a warm oven, the water, or the chemical solvent, will dry away, and leave the salt. This is a simple example of analysis.

Mix common salt, sand, and sawdust,—how are these to be separated? Add water to dissolve the salt;—the sand will subside, but the sawdust will float, or remain suspended in the solution; and if this be poured upon a fine sieve, the sawdust will remain, whilst the solution passes through, and the salt can be obtained from it as before. This is another example of analysis.

The chemist, therefore, by extensive knowledge of

the habitudes of substances with water, and more powerful solvents, is enabled to separate the components of soils; he adapts the process of analysis and the agents which he employs according to circumstances; but invariably takes the utmost care to educe, or draw forth, the several components as they naturally exist in the matter upon which he operates, and not to disturb or modify the arrangements of their elements to produce new compounds.

In illustration of the varied composition of soils fitted for the support of the different kinds of vegetation above described, their chemical analysis is here subjoined. "A good turnep soil afforded eight parts out of nine of Silicious sand, and the finely divided matter (that remained suspended, like the sawdust upon the water), yielded 63 parts of Carbonate of lime, 15 Silica, 11 Alumina, 3 Oxide of iron, 5 Vegetable and Saline matter, and 3 of Moisture.

"A soil remarkable for producing flourishing oaks afforded 3 parts of Carbonate of lime, 54 Silica, 28 Alumina, 5 Oxide of iron, 4 Decomposing vegetable matter, and 3 of Moisture.

"An excellent wheat soil gave three parts in five of Silicious sand, and the finely divided matter consisted of 28 parts of Carbonate of lime, 32 Silica, 29 Alumina, 11 Organic matter and Moisture.

"Of these soils the last was by far the most, and the first the least, coherent in texture; in all cases the constituent parts of the soil which gave tenacity and coherence, are the finely divided matters, and they possess the power of giving those qualities in the highest degree when they contain much alumina."

"A small quantity of finely divided matter is sufficient

to fit a soil for the production of turneps and barley; and a crop of turneps has been grown on a soil containing eleven parts out of twelve sand; a much greater proportion of sand, however, causes sterility."

"Vegetable or animal matters, when finely divided, not only give coherence, but likewise softness and penetrability; but neither they, nor any other part of the soil, must be in too great proportion; and a soil is unproductive if it consist entirely of impalpable matters. No soil is fertile that contains as much as nineteen parts out of twenty of any of the constituents that have been mentioned."

The power that different soils possess of becoming heated by the solar rays, and of retaining heat, will demand future attention; at the same time it must be evident that the general heat of the soil, particularly in spring, is of the highest importance to the rising plant. "The moisture in the soil influences its temperature, and the manner in which it is distributed through, or combined with, the earthy materials, is of great importance in relation to the nutriment of the plant."

"If water be too strongly attracted by the earths and their compounds, it will not be absorbed by the roots of the plants; if it be in too great quantity, or too loosely held amidst them, it tends to injure or destroy the fibrous parts of the roots."

The power of the soil to absorb water by capillary attraction depends in a great measure upon the state of division of its particles—the more divided they are, the greater is their capillary power; thus fine sand will absorb and retain more water than coarse sand, but each component of the soil has its particular capillary attraction; thus vegetable matters seem to be more absorbent than

animal matters when employed as manures, and animal substances are more so than compounds of alumina and silica, and these again are more absorbent than carbonate of lime and magnesia; but the chemist states that these differences may depend to some extent upon their mechanical division, and upon the surface exposed.

"Water, and the decomposing animal and vegetable matter existing in the soil, constitute the true nourishment of plants: and as the earthy parts of the soil are useful in retaining water, so as to supply it in the proper proportions to the roots of the vegetables, so they are likewise efficacious in producing the proper distribution of the animal and vegetable matter of manure; when equally mixed with it they prevent it from decomposing too rapidly, and by their capillary attraction the soluble parts are supplied in due proportions."

The foregoing are a few of the facts relating to the philosophy of soils which have been discovered by the chemist;—many others will be presented as we proceed throughout the Four Seasons.

Water appears to be the chief agent upon which plants depend for sustenance; and although seeds may be sown in a heap of insoluble sand, or of small lead shot, and will both germinate and flourish for a time, if such materials be kept moistened with water, experience teaches us that they will do so more perfectly, if some form of organic matter, in a decomposing state, be applied at the same time. Chemical analysis points out the reason of this; and when we come to the consideration of a plant in its advanced stage of growth, the theory of organic and inorganic manures will be investigated.

It is chiefly to the capillary attraction of the pores and fissures of the earth, that we are indebted for our

supplies of spring-water; when rain falls, a great portion is absorbed and retained by the surface for the maintenance of vegetation; whilst the excess not so employed percolates or filters through the soil, abstracts various saline and earthy compounds, until it meets with an impermeable stratum of rock; it then accumulates, and ultimately gushes forth at a lower level as a refreshing fountain.

A question now presents itself to the chemist,—how does water accumulate in the air to form the showers whose influence in promoting germination and growth in the Spring season has passed into the proverb—that "April showers bring forth May flowers?"

Experiment proves that such accumulation of water in the air is dependent upon a natural phenomenon called Evaporation, to denote a property possessed by the air, of causing the gradual wasting away, or the disappearance of the surface of water in the state of vapor; and such evaporation is proportionate to the temperature of the air, and the rapidity of its movement over the surface of the water.

Fill a broad shallow vessel with rain-water, collected before it has touched the earth, leave it uncovered and exposed to the air, in a situation sheltered from rain, and in the course of a few days of warm weather, the whole of the water will vanish, and leave the vessel perfectly dry.

The rationale of this simple experiment may be thus stated;—air contains heat, and this incites the liquid water to change into vapor or steam; this is lighter than air, but immediately blends with its volume, and is wafted away; fresh portions of air blow over the surface of the water and convert it into vapor as

before, until at length the whole of the liquid is thus consumed.

Evaporation is constantly proceeding throughout nature, and the parent source of the fresh water that diversifies and enriches the surface of the earth, is the vast ocean, although this may not be directly evident, as its waters are well known to be saline, bitter, and poisonous.

An experiment will elucidate this point;—collect a pint of rain-water, as already described; select two finger-glasses of equal size; measure half a pint of the water into each of these, and in one of these portions dissolve half an ounce of common salt.

Place both glasses in a situation sheltered from rain, but freely exposed to the air, and it will be found, in the course of a few days, that the water has evaporated from both, and has left in the one glass no solid deposit, but in the other the original half-ounce of common salt.

Pure water, solely consistent of Oxygen and Hydrogen,—and rain-water is very nearly pure—is totally volatile by natural or artificial heat; but common salt, and other saline and earthy compounds, capable of being held in solution by such water, are not similarly volatile, they are fixed, and accordingly remain when pure water has evaporated.

The waters of the ocean are saline and bitter from containing common salt, or chloride of sodium, and chloride of magnesium; these compounds are fixed at all natural ranges of atmospheric temperature; and accordingly when currents of air, or winds, blow over the wide expanse of the ocean, its absolutely pure water is incited to change from the liquid state to that of vapor, and thus to mingle with the air, to travel on the wings

of the wind far inland, where, meeting with depression of temperature, the vapor chills or condenses into drops, which the air cannot support, and therefore they fall through it as showers of rain, in obedience to the attraction of gravitation.

These showers partly sustain the vegetable productions of the earth, and partly accumulate to form springs; these gush forth as fountains, as already stated, and soon meander as streams upon its surface, and gradually spread and flow onward as rivers, which ultimately reach the ocean; from whence, by evaporation, the water again travels inland, again condenses as rain, accumulates as springs, rivers, and is again received by the ocean; thus performing an incessant round of utility, and displaying the power and goodness of God.

A similar process of evaporation is constantly proceeding from the surface of streams, rivers, lakes, and from the humid earth itself; the beneficial effects of this grand natural phenomenon are powerfully set forth in the Sacred Writings:

"God maketh small the drops of water; they pour down rain according to the vapor thereof, which the clouds do drop and distil upon man abundantly, and the tree of the field shall yield her fruit, and the earth shall yield her increase." Again,—"Thou visiteth the earth and waterest it, thou greatly enrichest it with the river of God which is full of water; thou preparest them corn when thou hast so provided for it; thou waterest the ridges thereof abundantly, thou makest it soft with showers; thou blesseth the springing thereof."

How eloquent, how beautiful, are these passages, how calculated to enlighten, adorn, exalt and purify the mind of the philosopher, and lead him to extol with rever-

ence and gratitude the Giver of every good and perfect gift!

The watery vapor thus present in the air is imbibed or attracted by soils with various degrees of energy, and is as much connected with their fertility as the direct absorption of the waters of the Spring showers. When this power of attracting aërial moisture is great, the plant is supplied with water even in the absence of rain; and the effect of the evaporation in the day is counteracted by the absorption of aqueous vapor from the air by the interior parts of the soil during the day, and by both the exterior and interior during night.

The compact, tenacious varieties of clay soils which absorb a great quantity of the water of the shower, do not attract a great quantity of moisture from the air during the absence of rain; they become hard, and the vegetation upon them is liable to wither away.

Chemical analysis of soils distinguished for their power of attracting aërial moisture, points out that they contain sand, finely divided clay, carbonate of lime, and organic manure, all so lightly bound together as to admit of the perfect access of air to a considerable depth; and the great utility of carbonate of lime, or chalk, and manure, consists in their conferring attractive powers upon the soil without rendering it adhesive and compact; sand likewise will destroy tenacity, but it appears also to impair this attractive power.

Soils which attract aërial moisture with the greatest avidity are always the most fertile; and very simple experiments upon this subject will afford means of judging of the value or productiveness of land.

One thousand grains of the soil, collected during dry weather, may be placed on a metallic "hot water plate,"

filled with boiling water; then let the soil be stirred with a piece of thick wire, until no dew or steam is deposited upon a cold glass plate or tumbler held about an inch above its surface.

This is a test that the soil is dried, and upon carefully removing it from the plate to the scale pan, the number of grain weights required to restore the original balance will indicate the quantity of water that was retained in the soil by capillary attraction, although it might have felt perfectly dry.

If this dried soil be left in the scale pan exposed to the air, it will gradually increase in weight by attracting aqueous vapor. The temperature of boiling water is directed to be used for the desiccation, because it is a good standard of comparison, viz., 212 degrees; and moreover such temperature will not alter the chemical nature of the soil by decomposing its organic constituents, like the greater heat of an open fire or lamp.

If it be required to ascertain the utmost quantity of moisture that the artificially dried soil is capable of attracting from the air, the following arrangement may be made:

Place the soil in an earthenware saucer, supported on an egg-cup, in the centre of a large dinner-plate full of

Fig. 7.

water; place a bell-glass, or a large earthenware jar, over this arrangement, that the rim of the glass or jar may stand in the water contained in the plate.

No liquid water can rise to the soil in the saucer, but the vessel with which it is covered contains air; this will excite the water to rise in vapor, and become saturated; a portion of this vapor will be attracted and condensed by the soil; examine its weight after a few hours, then replace it as before; and upon future examination, when it has ceased to gain weight, it may be considered to have attracted the greatest amount of water of which it is capable; again place it upon the plate to dry as before, and the water will evaporate.

Accurate experiments of this nature presented the first chemist who devoted his talents to agriculture with the following results.

I. One thousand parts of a celebrated soil from Ormiston in East Lothian, which contained more than half its weight of finely-divided matter, of which 11 parts were carbonate of lime, and 9 parts vegetable matter, when dried at 212 degrees, gained by exposure for an hour to air saturated with moisture, at a temperature of 62 degrees, 18 grains.

II. One thousand parts of a very fertile soil from the banks of the river Parret, in Somersetshire, under the same circumstances gained 16 grains.

III. One thousand parts of a soil from Mersea, in Essex, worth 45 shillings an acre, gained 13 grains.

IV. One thousand parts of a fine sand from Essex, worth 28 shillings an acre, gained 11 grains.

V. One thousand parts of a coarse sand, worth 15 shillings an acre, gained only 8 grains.

VI. One thousand parts of the soil of Bagshot Heath gained only 3 grains.

A very considerable degree of chemical attraction is discovered to exist between the aluminous portion of soils, and the organic matter of manure; thus it is preserved from too rapid decomposition, and from being carried away by water; or, in other words, the soil remains rich, and capable of yielding nutriment to vegetation, whilst very silicious soils have little or no such chemical attraction, and therefore often remain poor, and incapable of yielding generous support to their produce.

When soils are immediately situated upon a stratum of rock or stone, they become dry much sooner than when the sub-stratum is of marl or clay, which are strongly absorbent of water, and accordingly in some cases this is of great advantage to light sandy soils, as a reservoir of moisture upon which they can draw in time of drought for the support of their vegetation; in other cases, where the external soils are too absorbent, this property is corrected by the sub-stratum being of sand or gravel; this admits of the percolation of the excess of water.

In limestone districts, the actual soil is a kind of marl, generally only a few inches deep, but highly absorbent, and capable of supporting vegetation, because the limestone rock upon which it rests does not allow the water to escape by rapid capillary attraction; whilst, on the other hand, in sandstone districts, where the sandy soil, although absorbent, rests on absorbent sandstone rock, vegetation frequently suffers from the capillary attraction of the latter, withdrawing the water too rapidly; indeed, during the height of summer, it is no uncommon thing

to see the grass on sandstone districts parched and browned, whilst that on limestone districts is luxuriant and green.

The student of Nature must bear in mind, that the enormous amount of fifty-four trillions, four hundred and fifty-nine billions, seven hundred and five millions of tons of watery vapor, is sustained by the atmosphere, which is a mechanical mixture of the elements Oxygen and Nitrogen, and the compound Carbonic Acid; and that during all the wonderful vicissitudes of the Four Seasons, the atmosphere is never sensibly altered in the due proportion of its constituents.

Even when replete with solar heat, gained indirectly by convection from the warm surface of the earth, the air is simply expanded in volume, not altered in actual constitution; and when from local causes it has parted with a certain degree of heat, or become cold, it is simply contracted in volume; the pure abstract effect of artificial heat and cold upon air, is likewise attended by similar phenomena; this can be experimentally proved by the following arrangement:

Fig. 8.

A Florence flask is placed with its neck dipping beneath the water contained in a glass; the flask, although empty, in the ordinary acceptation of the term, is actually full of air; this has no tendency to escape,

because it is nearly of the same density and elasticity as the external atmosphere; neither has the water a tendency to enter but a very little way into the neck of the flask, because it is opposed by the included air.

Fig. 9.

Apply the flame of a spirit-lamp very gently to the bulb of the flask; its thin glass immediately conducts the heat to the air, which expands in volume, or becomes too large for the flask to contain, and accordingly a portion escapes from the neck, and bubbles through the water.

Allow twelve or fourteen bubbles to escape, then remove the lamp, and as the flask cools, water from the

Fig. 10.

glass will gradually rise into the neck of the flask, and at last become stationary.

The explanation of this experiment is as follows:— the air was expanded by heat, and a portion escaped; the remainder then contracted by cooling; and if the neck of the flask had not been under water, the external

air would have entered to restore the original volume; but being thus placed, the pressure of the external air forces water upward, to supply the place of the air that escaped.

Again apply the flame of the lamp to the bulb of the flask, until the expansion of the portion of air that it now contains, forces down the water nearly to the neck; then remove the lamp, and upon cooling the water rises as before; again heat and again cool, to the same degree; the air will invariably expand in the one case and contract in the other, and cause the water to fall and rise as many times as may be thought proper; the same results will ensue upon alternate exposure of the flask to sunshine and shade.

When the air has contracted for the last time, lift the flask with one hand, that its mouth may be only half an inch beneath the water, and take a cork between the fingers of the other hand, and dip it beneath the water, to close the mouth of the flask; then it may be placed to stand upon a wooden or pasteboard ring, as shown in the next engraving; the water that was in the neck of the flask, will now occupy part of its bulb; the air will occupy the remainder.

Fig. 11.

Fig. 12.

Provide a small wax taper, about one inch and a half long; attach it to the end of a bent wire, rather exceeding the height of the flask; kindle the taper, remove the cork, and gently let the taper down the neck into the bulb of the flask, the flame will be found to continue for a time, with the same brilliancy as in the open air; at last it is extinguished.

These experiments are to prove that the pure and abstract effect of heat from the flame of the spirit-lamp conducted through the glass, is merely to cause expansion of the volume of the air, and that of cold, its contraction; and that no chemical change in the proportion or nature of its constituents is effected, or the flame of the taper could not exist for a moment when plunged into air subjected to these ordeals.

Whether the air be hot or cold, it invariably contains the relative proportions of nitrogen and oxygen, which have been so frequently named; the latter element supports the flame of the taper for a time, but why does it not continue as it would do in the surrounding air? Because actual combustion in air effects its decomposition; chemical changes are instantly summoned into activity; the chief elements of the wax taper are Hydrogen and Carbon; at an elevated temperature both combine with Oxygen, to form in the one case Water, and in the other Carbonic acid; and the flame or chemical change ceases when the given volume of oxygen is thus abstracted, because these results of combustion, water and carbonic acid, and the liberated nitrogen, can yield it no support.

The flame of the spirit-lamp employed for heating the flask, decomposed the free air for its support; and in every case of the combustion of ordinary fuel, the air

is similarly decomposed, the elements of the fuel combining with the oxygen, and producing water and carbonic acid, and liberating nitrogen, for which they have no attraction.

Animal respiration effects changes upon atmospheric air, closely analogous to those of combustion; air that has passed from the lungs is rendered perfectly unfit for the further support of life or flame; the fact as regards flame may be experimentally proved by a very simple arrangement of apparatus, of which a sketch is given below.

Provide a glass vessel, in the form of a quart bottle, having the lower part removed; withdraw the ground-glass stopper, and then place the glass, to stand in a shallow pan of glass or earthenware, containing about two pints and a half of water; introduce a lighted taper through the neck of the glass, and ascertain that the included air supports flame; then remove the taper, lift the glass perfectly out of the water, and move it backwards, and forwards in the open air, to allow the products of the flame of the taper to escape; the glass will thus become filled with fresh air, and is to be placed in the water as first directed.

Fig. 13.

Fig. 14.

Make a deep expiration, or sigh, of air from the lungs, apply the lips closely around the neck of the glass, and draw air from it into the lungs; as this is done, water will rise from the pan into the glass, and when it nearly reaches the lips, expel air from the lungs, until the water falls to its original level; again inhale, and again exhale, then remove the lips from the neck of the glass, and immediately insert the stopper.

Kindle the taper, remove the stopper, and introduce the flame; it will be extinguished as effectually as though plunged into water, not even a glowing spark will remain; therefore the air must have sustained some most extraordinary change during its brief contact with the lungs; it is as follows.

The chemist has discovered that Carbon is an element of the blood, and in that wonderful fluid, it has a powerful affinity for oxygen; therefore, when the blood is exposed to the action of air inhaled by the lungs, carbonic acid is instantaneously produced, whilst nitrogen is liberated, and both compound and element are to be found in the exhaled air, which is perfectly unfit for the further maintenance of life, or the support of flame.

The manner in which these mephitic results of respiration are prevented from injuring vitality, presents another wonderful example of the Power and Goodness of the Creator.

From experiments conducted upon Aqueous vapor, Nitrogen and Carbonic acid, the chemist discovers that the two first are lighter, and the latter heavier, than a similar volume of air of the same temperature; therefore, reasoning *à priori* upon this fact, the most obvious inference would be, that when they are con-

jointly exhaled from the lungs, the aqueous vapor and nitrogen would ascend, the carbonic acid descend, and thus leave a mid-path for the inhalation of fresh air.

How different is the action, induced by the refined and miraculous power of vitality! The temperature of the living body exceeds that of the surrounding air; the aqueous vapor; nitrogen and carbonic acid are all exhaled from the lungs in a heated state; the action of vital heat is not merely to expand the exhaled matters to more than their original volume, but to render aqueous vapor and nitrogen still lighter than they are inherently, and to render inherently heavy carbonic acid, equally light with them; accordingly, all conjointly ascend swiftly from the respiratory organs, without vitiating the fresh air that immediately enters the lungs to discharge its functions, and in its turn to undergo similar change and disposal!

This fact admits of experimental illustration, by a very simple arrangement; provide a cylindrical glass, about eighteen inches long and four inches in diameter, closed at one end, and its rim ground smooth; also a piece of flat plate-glass, to cover this, and about a pint of lime-water; this is prepared by adding an ounce of quicklime to a quart of water, contained in a glass bottle, corking it closely, shaking it several times, then allowing it to settle, and carefully decanting a part of the transparent and colorless liquid into a clean bottle, that must be provided with a glass-stopper.

These preparations being completed, place the glass jar, with its rim, just below the lower lip, and breathe across it twice or thrice; then cover the rim with the glass plate, and set the glass jar upon the table.

Remove the stopper of the bottle containing the lime-

water, then slide the glass plate a little on one side, that sufficient room may be made for pouring about half the lime-water into the glass cylinder; it is then to be closed with the glass plate, and shaken two or three times, for the lime-water to come into contact with the air that it contains; no change will be perceptible in the clearness of the lime-water; pour it away; then hold the glass cylinder in an inverted position, with its rim just above the upper lip, and breathe beneath it twice or thrice; close the jar with the glass plate, and place it to stand on the table; then proceed as before, to pour in the rest of the lime-water; and upon agitation it will lose transparency, and become milk-white.

The chemist presents the following explanation or rationale of these experiments: lime is slightly soluble in water, and in that state has a strong attraction for carbonic acid, or, in technical terms, it is a test of carbonic acid, forming white carbonate of lime; this it will do slowly, even from the atmosphere.

The aëriform matters were exhaled from the lungs in a heated state, therefore they did not fall through the air contained in the glass cylinder held with its rim upwards, as in the first experiment, but ascended and were lost in the surrounding air; had they fallen, the lime-water would have detected the carbonic acid, by the immediate formation of carbonate of lime or chalk.

On the other hand, when the glass cylinder was held with its rim downwards, the heated exhalation from the lungs ascended, and displaced the air that it originally contained, and the lime-water immediately detected the newly-formed Carbonic acid, by combining with it to produce Carbonate of Lime or Chalk.

Thus do the results of respiration and of combustion

ascend and diffuse themselves throughout the atmosphere; but they are destined to perform a ceaseless round of changes, the consideration of which will claim our attention at a future season; for in the vast and perfect laboratory of Nature, nothing is lost, nothing is destroyed, or rendered worthless.

The germination of seeds effects a chemical change upon the air, analogous to that now described; this may be experimentally proved: place a handful of peas in a quart bottle, moisten them with water; introduce a lighted taper for a moment, to prove that the air is unvitiated, then close the mouth of the bottle with a ground stopper, place it in a warm situation, and in a few days germination will ensue; the production of carbonic acid, and the liberation of nitrogen, may then be proved by the extinction of the flame of the taper when introduced into the bottle.

From experiments similar in principle to the foregoing, but conducted with the utmost skill and precision, the chemist concludes, that combustion, respiration, and germination, are active in producing changes upon the nature of the air, and yet he fails in detecting any accumulation of mephitic matters: this is partly on account of the utterly insignificant volume of air—only a few gallons—upon which he can operate with analytical agents, and partly on account of a discovery that he makes regarding plants when in full vigor, and especially when under the direct influence of solar light, having the miraculous property of decomposing carbonic acid, and thus restoring the just balance of the atmosphere: this will demand future consideration.

It must now be remarked, that the presence of uncom-

bined oxygen is requisite for the phenomenon of germination to proceed; and the chemist discovers that such condition is wonderfully provided for in the vast atmosphere, in which oxygen is only mingled with, and not combined with nitrogen.

The presence of uncombined oxygen is indispensable, that it may exert chemical affinity for a portion of the Carbon of seeds, and convert it into Carbonic acid; and unless seeds thus lose carbon, they will not germinate.

Place seeds in elementary nitrogen, or in compound carbonic acid, supply them with a due temperature and water, but instead of germinating, they will rot, because nitrogen has no affinity for carbon under these circumstances, neither has carbonic acid, as it already contains that element. A vigorous and healthy plant will soon wither and die, if placed in nitrogen or carbonic acid, a phenomenon analogous to the cessation of animal life, when imprisoned in the same media.

On the other hand, place seeds in pure elementary Oxygen, supply them with a due temperature and water, they will germinate with extreme rapidity; but the action is morbid, for carbonic acid is formed at the expense of their carbon, in great excess, and they soon decay; so when an animal is imprisoned in the same medium, respiration becomes hurried by the unnatural escape of carbon from the blood, and death quickly ensues, from the intense excitement into which the system is thrown.

We have therefore reason to admire the power and goodness of God, in preserving the wonderful uniformity in the constitution of the air in every terrestrial locality,

and rendering it alike congenial to the welfare of animal and vegetable life.

The negative properties of the large volume of nitrogen, restrain the positive properties of the small volume of oxygen; this element is therefore slowly received by animals and vegetables, and without morbid excitement, because their secretory organs are compelled to perform the preliminary office of seeking and of separating it from a state of admixture with nitrogen.

In connection with this subject it may be remarked, that unless the large volume of negative nitrogen were existent in the atmosphere, all the materials which are now advantageously employed as sources of fire and artificial light, would consume with a degree of rapidity entirely disproportionate to their abundance upon the earth, or to the limited power of mankind to extract them from its strata.

Another phenomenon of Spring, upon which the germination of seeds and the growth of plants depend, now demands attention.

The thaws and floods of February leave the earth saturated with water, and unfit for the reception of seeds; but the aërial currents, familiarly called "March winds," which reach the shores of England, cold and almost anhydrous from sweeping over the frozen continent of Europe, are ordained to evaporate the surplus of such moisture, and to dry the soil sufficiently for the husbandman to commence his active labors.

In the ensuing month, the evaporated water hovers above on the wings of the clouds, and ultimately condenses into drops, and descends as the showers of April, to fertilize the earth from whence it ascended.

Hence the origin of the proverb—March comes in

like a lion, and goes out like a lamb—meaning that the weather at the beginning of the month is generally rough and boisterous, but in the end softened and subdued.

Again,—a peck of March dust is worth a king's ransom—Why? Because it indicates to the husbandman the probable continuance of dry weather, and upon the proper dryness of the soil, for the reception of the seed, at this season, that it may not rot and decay, depends the produce of the autumnal harvest.—A dry and cold March never begs its bread,—because it prepares the earth for seed-time; but—a wet March makes a sad August—because, urged by necessity, the husbandman is obliged to cast seed into the ground saturated with the waters of February, and much is spoiled, and yields no crop in August.

"'The late Spring makes the fruitful year;" for if very mild weather happen in March, nature assumes the aspect which properly belongs to April; buds and blossoms are pinched by the night frosts, and are either killed, or so injured that they produce neither flowers nor fruits in due season; and hence the expression,—'March flowers make no summer bowers.'

These proverbs must not be despised for their homeliness; they convey philosophical truths, and prove how accurately our ancestors studied the changes of the Four Seasons, though undirected by refined scientific knowledge.

The chemist can offer no satisfactory explanation of the formation of clouds or rain; but so far as his researches have been carried, they tend to the conclusion, that clouds and mists consist not of actual drops of water, but of myriads of excessively thin vesicles of water, simi-

lar to soap bubbles; if clouds, mists, and fogs, consisted of drops, their fall would be rapid, for mathematicians calculate, that a drop whose diameter amounted to a thousandth part of an inch, in obeying attraction of gravitation would acquire a velocity of nine or ten feet per second; whereas we see clouds hover at a small elevation for hours; and they are transported from the sea, lake, river, or marsh, from which they are raised, far into the country, or to the tops of mountains, where the requisite supply of moisture cannot be had in any other way.

A scientific traveler in the Alps was enveloped in a mist which was almost stagnant; he was greatly surprised at the size of the drops—as he imagined them to be—float slowly along instead of falling; some of these were larger than the largest peas, and upon close examination proved to be vesicles of water of extreme tenuity. Clouds are probably formed when two volumes of air of different temperatures, and both saturated with aqueous vapor, meet, and mix together; but the cause of the production of vesicular vapor, and the fall of rain, remains a mystery.

"He causeth the vapors to ascend from the ends of the earth: He bindeth up the waters in the thick clouds, and the cloud is not rent under them.

"He weigheth out the waters by measure.

"Canst thou tell the balancings of the clouds, the wondrous works of Him which is perfect in knowledge?"

Leaving, therefore, these recondite yet beneficial phenomena, let us proceed with such as admit of interpretation through the medium of experiment.

The porous surface of the earth has been shown to

be peculiarly fitted for the reception of water, and its accumulation as springs; but this beneficial result could not ensue if the earth were a good conductor of heat, because such imponderable agent would then travel beneath the surface, and vaporize or dry up the whole of the water.

The Creator, in His power and goodness, has constituted the earth of materials that are incapable of conducting heat to any great extent, and therefore it chiefly remains at or near the surface, where it is needed for the welfare of animal and vegetable life.

In the height of summer, when the surface of the earth is parching hot, if we excavate only a few feet beneath, it feels many degrees colder: and in the depth of winter, when frost is on the surface, if we proceed similarly, it feels several degrees warmer, and is always above 32 degrees, or the clods of earth thrown out by the spade would not be soft and moist; they would be hard and dry as ice.

Thus, the imperfect, or bad conducting power of the earth as regards heat and cold,—the terms being merely relative,—is the reason that springs of water do not wholly escape as vapor in summer, and that they do not wholly become solid ice in winter.

The coolness of a draught of water, drawn from a deep spring in summer, and its comparative warmth from the same source in winter, is a familiar example of the point in question; indeed, during the intense cold of winter, as the water of a deep spring gushes to the surface of the frosted earth, it actually steams, or, in more chemical language, its warm vapor undergoes condensation by the cold air into which it escapes. At the depth of 100 feet from the surface, the temperature of the earth

is the average temperature of the climate, and differs with the latitude; thus at Wadso, in Lapland, it is 36°, at St. Petersburgh, 40°, in England, 52°, at Paris, 54°, at Rome, 61°, and at Cairo, 70°.

Air and water are non-conductors, and the earth is an extremely imperfect conductor of heat; good conductors of this extraordinary imponderable agent do not, generally speaking, occur abundantly upon the surface of the earth, which they would render sterile, but as metallic treasures deeply hidden in its bosom, where there is no life, and from whence they are artificially extracted, and rendered subservient, amongst thousands of other uses, to the formation of the ploughshare, and the sickle, for tilling the ground, and reaping its produce. A few experiments regarding the difference between good and bad conductors of heat, can be easily performed.

Provide a metallic "hot-water plate," as commonly used at the dinner-table, then spread evenly fine iron filings over one half of its surface, and fine dry sand over the other half, to the depth of three quarters of an inch, and place a lump of tallow about the size of a pea upon each; lastly, pour boiling water through the hole in the rim of the plate, until it is filled. The iron and the sand are thus exposed to the same degree of heat, but they will not conduct it with the same facility, as will be proved by the tallow melting on the iron in the course of a few seconds, whilst it remains unmelted on the sand for many minutes afterwards.

The difference between the conducting power of a metal, an earth, and an earthy compound, may be further illustrated by the following simple and instructive experiment:—Provide solid cylinders, of these three

materials, viz., iron, sandstone, and chalk; let them be one inch in diameter, and six inches long, and perfectly flat at each of their ends.

Place a cup, containing an ounce of tallow, upon the warm hob of the grate; and when the tallow is perfectly melted, dip into it for about half an inch one end of the iron cylinder, and then lift it out; a portion of tallow will adhere, and quickly become solid, because the iron, by good conducting power, deprives it of the heat of fluidity. Dip one end of each of the other cylinders in the same way; they will attract, or absorb, a considerable portion of the melted tallow, and some time will be required before it will become equally solid with that on the iron cylinder, because sandstone and chalk have not sufficient conducting power to deprive it of heat in a similar degree.

Dip the end of all three cylinders again, and lift them out, and when the tallow becomes solid, dip them again, and lift them out, until they have all obtained an equal coating of tallow; then allow them to cool.

Pour boiling water into a "hot-water plate," and place the three cylinders to stand upon it, at equal distances, with their coated ends uppermost, as shown in the annexed sketch.

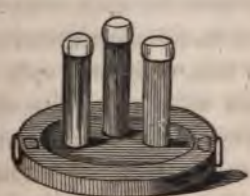

Fig. 15.

In the course of a few minutes, the iron will again

prove its good conducting power, by melting the tallow; but the sandstone and chalk will prove their bad conducting power by the tallow remaining solid during the whole time that the water is cooling down to common temperatures.

When heat is applied to the surface of good conductors, their entire mass will eventually become equally elevated in temperature; whilst, on the other hand, with bad conductors, the heat will chiefly remain upon the point to which it is first applied, and the great part of their mass gains no increase of temperature.

If, for example, the iron cylinder be felt when the whole of the tallow has fairly melted from its upper end, this will be found as hot as the lower end; if the cylinders of sandstone and chalk be felt, their lower ends alone will be found hot, and by moving the finger slowly upwards, the limited extent to which they have conducted heat will become sensible.

By reversing the arrangement of the last experiment, namely, by applying heat above, instead of beneath the cylinders, it can be proved that neither the conducting power of the iron, nor the non-conducting power of the sandstone and chalk, are in the least degree affected or modified.

Let the iron cylinder be again coated with tallow, but pare away all from its circular extremity, that it may now stand firmly upon this, and have only a ring of tallow about half an inch wide around its circumference; do the same with the cylinders of sandstone and chalk; then set the three, at equal distances, within a circle, similar in diameter to the bottom of the "hot-water plate," that they may form a tripod for its support; this arrangement must be made upon a steady table; then remove the plate,

without disturbing the cylinders; fill it with boiling water, and carefully replace it to stand upon them, as represented in the annexed sketch.

Fig. 16.

The three cylinders will now be subjected to heat, applied from above, instead of from below, as in the last experiment; but this arrangement will cause no difference in their conducting or non-conducting power, as will be proved in the course of a few minutes, by the ring of tallow melting from the iron cylinder, whilst that upon each of the other cylinders remains solid as before.

Thus in Nature, solar heat impinges on the surface of the earth, and there chiefly remains, as it cannot escape downwards on account of the bad conducting materials of which the earth is constituted.

During a hot day, a sandy district is perfectly dry and dusty; but upon removing the surface for the depth of a few inches, damp sand appears, proving that heat has not been conducted downwards to any great extent.

The reason that heat does not accumulate to a destructive extent upon the earth, will appear when we are considering the chemical phenomena of another Season.

In some countries, Spring and Winter are hardly

known, vegetation being constantly luxuriant, but sudden showers or rather torrents of water, periodically fall, and are absorbed by the capillary structure of the non-conducting soil, and there treasured up for due transmission to vegetation in future seasons of drought.

Other countries, from their low level, are subject to periodical inundations, by the rise of large rivers; these saturate the earth with water, and then subside, leaving a sediment or mud, consisting of finely-divided earthy and organic matter, which acts as a powerful stimulus to the germination and growth of seeds. This phenomenon is alluded to in the following beautiful metaphor—"Cast thy bread upon the waters, and thou shalt find it after many days."

In oriental countries, bread is synonymous with rice, which is cast upon the soil, saturated by the inundation, and apparently lost, but appears in due season, as a plenteous harvest.

We may now resume our investigation concerning the phenomena of germination and growth, which we quitted at the time that the seed had put forth its radicle and plumula.

The radicle sends out its fibres amidst the soil, in search of moisture and soluble matters, and by an incomprehensible vital power, transfers them into the body of the plant, where they undergo mysterious elaboration to form the fluid called sap.

The terminal fibres of the radicle are so minute as almost to defy detection by the aid of a microscope, and, if injured, they will not fully exert their proper functions; therefore, in transplanting, we always endeavor to avoid wounding them with the spade, by digging some distance around the stem, and thus carrying away with the plant

a large ball of earth through which the terminal fibres have not penetrated.

This precaution protects the radicle, and also the plant, from sustaining the derangement of its functions that would ensue, if it were rudely torn up, and suddenly transplanted to a soil physically and chemically different from that in which it originally germinated and grew; the plant continues to draw for food upon its parent clod of earth, until its organs are enabled to pierce beyond such limit, and to become inured to the change of nutriment presented by the neighboring soil.

The chemist is acquainted with numerous substances which act as poisons upon the animal frame; of these, white-arsenic, corrosive-sublimate, blue-vitriol, prussic acid, and opium, may be cited as examples; and he discovers that any of these, if dissolved in water, and applied to the roots of a plant, will soon cause it to languish, droop, and die.

Many experiments have been made upon this destruction of the vitality of plants by poisonous substances; the following are a few of the most remarkable.

Beans were watered with a solution of white-arsenic; they faded in the course of a few hours, then became yellow, and in three days were dead.

A lilac was killed by the introduction of a portion of solid white-arsenic into a cut made in one of its branches; and a similar effect was produced by corrosive-sublimate.

Beans were killed by prussic acid in the course of a single day, and deadly nightshade in four days; while spirit of wine killed the plant to which it was applied in a few hours.

An experiment can be easily made regarding the poisonous action of a metallic solution upon a plant.

For example, water a succulent plant with a solution of blue vitriol (sulphate of copper) until it die; then cut its stem across with a perfectly clean steel knife; and that the poisonous compound has been transferred to the plant, and caused its death, will be evident by bright metallic copper appearing on the knife-blade.

All things are so miraculously adjusted throughout Nature, that the earth seldom if ever presents the roots of plants with poisonous matters, but in their stead soluble compounds of potash and lime, which, under the influence of vitality, promote the elaboration of healthy sap or vegetable blood. The chemist can throw but very little light upon the composition of sap, and no analysis unto which it has been subjected, can be regarded as correct, on account of the difficulty of obtaining it in a normal state, or free from other juices of the plant; the cause of its motion or circulation is also a mystery; it is observed to travel through the stem and the branches, and chiefly towards the leaves; it enters their peculiar structure as a comparatively thin fluid, containing a large amount of water; and by the combined agencies of heat, air, and light, much of this is evaporated in a pure state, or in other words, the sap becomes thickened, or concentrated, and excited to form new proximate principles, which increase the growth of the entire plant.

Upon close examination, the chemist discovers this evaporation to be enormous; for example, a large sunflower was proved to lose one pound four ounces, and a cabbage one pound three ounces, of water during twenty-

four hours; and many plants were proved to lose one hundred times their weight of water during three months.

This evaporation of water from plants may be proved very readily, by covering them with a cold, dry, bell-glass, for in the course of a few minutes its interior will become lined with small drops of water resulting from the condensation of the vapor; and that it ensues chiefly from the lower surfaces of the leaves, may be shown by placing them between two cold, dry plates of glass, as represented in the sketch below.

Drops of water will thus condense most abundantly upon the glass plate, which is opposed to the lower surfaces of the leaves; "their organization is such, as to render these surfaces the most apt for the escape of watery vapor; but in some plants the upper surfaces are said to be most active."

Fig. 17.

As evaporation thus proceeds from the leaves, they incessantly demand a fresh supply of moisture from the roots; and if the soil be too dry, or water not abundantly furnished to meet the demand, the plant will inevitably sustain derangement of its functions.

Plants are frequently "blighted" during early Spring, by dry winds, for when branches and leaves are first put forth, they are extremely succulent, and part with water so readily, that during a dry easterly wind this loss by

evaporation cannot be rapidly compensated for, by the capillary attraction of the roots.

The drooping of a plant during a hot day, mainly depends upon the extreme evaporation of water that has been excited from the leaves, and the inadequacy of the terminal fibres of the roots to collect more with sufficient rapidity from the arid earth; if then water be artificially added to it, the plant revives, sometimes with extraordinary quickness.

Leaves have not only the power of transpiring the vapor of water, but likewise of absorbing it under certain conditions; thus a plant, drooping beneath the heat of Summer, will soon revive if placed in a damp cellar; the leaves absorb the damp, or vapor of water, and through its genial influence the plant speedily regains its wonted strength and beauty.

The leaves, in their exercise of these functions of evaporation and of absorption, are of vital importance to plants; and, upon stripping them away, the plants suffer in health, or suddenly die.

The further consideration of the vital functions of plants upon surrounding media, will be presented in the next Chapter; and in proportion as we extend these researches, so shall we have cause to appreciate, with admiration and gratitude, the power and goodness of the Creator. "He causeth the grass to grow for the cattle, and herb for the service of man: that he may bring forth food out of the earth."

CHAPTER II.

SUMMER.

SUMMER arrives, the sun attains its zenith of splendor and heat, and under its influence the buds and blossoms of Spring have transmuted into foliage and flowers; they adorn and diversify the scenery of the earth; they captivate our senses, by their exquisite structure, and their delicious fragrance; they all exert specific functions upon surrounding media, for maintaining the harmony and order of the Creation; let us therefore resume our investigation regarding vegetable growth.

The seed weighed only a few grains, when cast into the earth in Spring; it has now produced a plant, weighing many ounces, and the general increase of bulk which has ensued throughout the vegetable kingdom, cannot fail to elicit a remark from the most listless observer: let us endeavor, if possible, to account for this growth upon chemical principles.

If the chemist undertake the ultimate analysis of a vegetable, or the generality of vegetable products, for example, Lignin or woody-fibre, Sugar and Starch, he finds them to yield nearly half their weight of Oxygen and Hydrogen in the proportions requisite for the constitution of Water; and nearly half their weight of Carbon; this will be evident, upon reference to the tabular statement at pages 34 and 35 of the Introductory Chapter.

that now adorns the earth, and likewise the important proximate principles obtainable from these?

The experienced chemist, in reply, states, that there is abundance of Carbonic acid for this purpose, naturally existing in the air, its weight being expressed by the enormous sum of Five trillions, two hundred and eighty-seven billions, three hundred and five millions of Tons.

In other words, the number for expressing this quantity of Carbonic acid, vastly exceeds that for expressing the number of Seconds which have elapsed since the Creation, namely, one hundred and eighty-four billions, four hundred and fifty-four millions, one hundred and fifty thousand, and four hundred!

In addition to the enormous weight of Carbonic acid, just stated, it must be remembered, that the respiration of man and animals, the processes of combustion, the phenomena of the germination of seeds, the ripening and the decay of fruits, the putrefaction of organic matters, are hourly sending forth incalculable quantities of the same compound into the atmosphere.

In fact, the chemist can only determine with tolerable accuracy the weight of the quantity of carbonic acid exhaled by human beings; and when this is done, it strikes the mind with wonder and amazement, at the stupendous scale upon which natural phenomena proceed, under the guidance of Omnipotence.

The volume or bulk of Carbonic acid produced by a healthy adult individual in twenty-four hours, amounts to about fifteen thousand cubic inches, containing about two thousand six hundred grains of Carbon, or about six ounces, or to between thirty-seven and thirty-eight pounds, from every hundred persons; so that, assuming

thirty seven-pounds as the average, one million of human beings would thus exhale into the surrounding air, a compound containing no less than three hundred and seventy thousand pounds, or upwards of one hundred and sixty-five Tons of Carbon!

The total population of the globe is estimated at Seven hundred and sixty millions; and accordingly, on the above data, they would exhale Carbonic acid, containing one hundred and twenty-five billions, and four hundred millions of Tons of Carbon!

"If there were not excellent, and adequate adjustments, which compensate for, and virtually remove, this poisonous effluvium of Carbonic acid,—for poisonous it must be called in reference to its abstract effect upon the animal system, as mentioned at page 27,—it would soon overwhelm us;" and we have indeed occasion to extol the power and goodness of God, when we discover the miraculous workings which He has ordained, for the disposal and uses of the agent we are considering.

In the first place, Carbonic acid is a vapor,—escaping from the lungs in a heated state, by which it gains wings, as it were, and is instantly wafted away; in the next place, it has what is termed "diffusive property," meaning the power of uniformly blending with the enormous volume of the atmosphere, so as to elude detection in hurtful quantity; and lastly, as most particularly applicable to the present inquiry, "this carbonic acid, which is poison to us, is the food of plants, and of the whole vegetable world; they absorb it into their systems, and whilst they retain the Carbon they emit the Oxygen, and so feeding themselves, they purify our Atmosphere."

"Here, then, the Chemist reveals the mutual depend-

ence of the animal and vegetable kingdoms," and presents for our admiration and gratitude a magnificent example of the power and goodness of God,—"Who hath created nothing in vain; and Whose tender mercies are over all His works."

This miraculous process of the analysis, or decomposition of Carbonic acid by the vegetable kingdom appears to be constantly active, though certainly in the greatest degree, under the direct influence of solar light and it admits of most satisfactory illustration by simple experiments.

Provide a quart wide-mouthed stoppered bottle, of flint-glass; remove the stopper, and apply a slight touch of pomade to its ground part, and likewise to that of the neck of the bottle; replace the stopper, turn it gently round twice or thrice, to distribute the pomade thinly and evenly between the ground surfaces, to make an air-tight joint; then again remove the stopper, and pour in a few spoonfuls of water.

Kindle a wax-taper, attached to the end of a bent wire, as in the experiment described in page 67; introduce this into the bottle, and keep it there until the flame ceases; then withdraw the extinguished taper, and quickly introduce a sprig or two of growing mint; lastly, in-

Fig. 18.

sert the stopper, tie it over with a string, that it may not be forced out by expansion, and then place the bottle in the sunshine: the arrangement is here represented.

The combustion of the taper in the confined portion of the air, has withdrawn the greater portion of its oxygen, and formed carbonic acid, and liberated nitrogen; the rays of the sun will excite the leaves of the mint to decompose the Carbonic acid, to secrete its Carbon and to liberate Oxygen, which, blending with the unaltered Nitrogen, will restore the contents of the bottle to their original condition; this fact is proved by removing the stopper after a few days, and again introducing the lighted taper; it will then burn, as it did at the outset of the experiment.

If a portion of air be vitiated by respiration, as in the experiment described at page 69, upon introducing a few sprigs of mint into the glass, and then exposing the arrangement to sunshine, a similar result will be obtained.

Sprigs of mint are directed to be used in these experiments, as they were the simple means by which this important discovery was originally made, as follows:— A chemist found that air was not vitiated by the growth of a sprig of mint, kept in it for some months; he therefore thought it possible that the process of vegetation might restore the air injured by burning candles; accordingly he put a sprig of mint into air in which a wax candle had burned out; and ten days afterwards he found that another candle burned perfectly well in it; and then to verify the conclusion, he divided the injured air into two separate portions, putting the plant into one of them, and merely leaving the other; he always found that a candle would burn in the former, but not in the latter.

This restoration of the air, the chemist found to depend upon the health and vegetating state of the plant; for though he kept many fresh leaves of mint, in a small quantity of air, vitiated by combustion, and changed them repeatedly for many days, they did not ameliorate the state of the air.

This remarkable effect was not dependent upon anything peculiar to mint, because several portions of vitiated air were perfectly restored by sprigs of balm, and then groundsel, spinach, and other plants were used with like effect, to prove that it did not depend upon aromatic principles.

The conclusions drawn by the chemist from these experiments he thus stated:—These proofs of a restoration of air by plants in a state of vegetation, though in a confined and unnatural situation, cannot but render it highly probable, that the injury which is continually done to the atmosphere by the respiration of such a number of animals, and the putrefaction of such masses of both animal and vegetable matter, is, in part at least, repaired by the vegetable creation; and notwithstanding the prodigious mass of air that is corrupted daily by the above-mentioned causes, yet, if we consider the immense profusion of vegetables upon the face of the earth, growing in places suited to their nature, and, consequently, at full liberty to exert all their powers, both inhaling and exhaling, it can hardly be thought but that it may be a sufficient counterbalance to it, and that the remedy is adequate to the evil."

The experiments now detailed, were made upwards of seventy years since, when refined methods of operating were unknown, but they have received full corroboration from recent researches, conducted with accurate apparatus.

Vegetation will not proceed, in a mixture of Oxygen and Nitrogen, in whatever proportions they may be blended together, because there is no compound of Carbon present to yield solid matter, and when the above elements are mingled in the proportions in which analysis proves them to constitute the chief constituents of the air, the addition of eight or ten per cent. of carbonic acid forms a medium, fatal to plants, when in the shade, but not when exposed to solar light.

The proportion of carbonic acid naturally present in the air, is certainly essential for the welfare of animal life, although the chemist is unable to ascertain the manner in which its influence is exerted.

Experiments similar in principle to the foregoing, but conducted with the utmost refinement, and unwearied patience, led to the conclusion that the vegetable kingdom, though a silent, is an ever-active agent in sustaining the uniform balance of the constituents of the atmosphere, and in contributing its share to the maintenance of the harmony and order of the works of God.

The phenomena that we have been considering are eloquently set forth in the following words:—

"From these discoveries we are assured that no vegetable grows in vain; but that, from the oak of the forest to the grass of the field, every individual plant is serviceable to mankind, if not always distinguished by some private virtue, yet making a part of the whole which cleanses and purifies the atmosphere. In this the fragrant rose and deadly night-shade co-operate; nor is the herbage nor the woods that flourish in the most remote and unpeopled regions unprofitable to us, nor we to them, considering how constantly the winds convey to them our vitiated air, for our relief and their nourishment.

And if ever these salutary gales rise to storms and hurricanes, let us still trace and revere the ways of a beneficent Being, who not fortuitously, but with design, not in wrath, but in mercy, thus shakes the water and the air together, to bury in the deep those putrid and pestilential effluviæ which the vegetables on the face of the earth had been insufficient to consume."

The imponderable agency of solar light, though not required in the early stages of germination, becomes, at a more advanced season, of the utmost importance to the welfare of the growing plant.

For example, take a flourishing plant, with leaves full verdant, supply it with a due share of heat, air, and water, but shut it in darkness for a few days; then withdraw it from such imprisonment and remark its appearance; the leaves are no longer vigorous and green, they are languid and pale;—why this change?

Because the stimulus of light was denied them, and the vessels of the plant could not elaborate those principles, from the earth, water, and air, which are essential to its welfare; the physical structure of the leaves has also suffered derangement, and they are incapable of reflecting a proper amount of the green rays of light.

Now expose the languid and pale plant to the sunlight for a few hours, its functions will be excited to proper action, it will regain health and verdancy.

The generality of plants have a predilection for solar light, and if they be either accidentally or intentionally placed in gloom, through which penetrates but one ray, their leaves and branches turn and bend towards the spot upon which its effulgence falls, as if eager to exchange their pallor and languor for color and health.

Solar light excites strange chemical affinities in grow-

ing plants, the reason of which is not understood; thus some leaves are acid in the morning, tasteless at noon, and bitter at night; some flowers are white or blue, according to the intensity of the light; many fruits are more acid in the morning than in the evening; some flowers expand their petals to meet the sunshine, others close them against its power.

The influence of light in promoting the color and ripening of fruits is also remarkable; select a peach for example;—the portion of it which is fully exposed to light, has a brilliant crimson hue, whilst that in shadow, or merely covered by a leaf, is pale green and yellow; the taste of the one part is more luscious than that of the other, because light has there stimulated the elaboration of the most sugar; hence, also, the sweetest fruits are generally found in southern climates.

On the other hand, some plants, when grown in the full glow of light, become unfit for food; this is the case with celery: it grows rank, green, and bitter; but by banking earth around the stem to exclude the light, it becomes blanched, and pleasantly aromatic to the taste, with the exception of the tuft just above the ground, which remains dark green and hurtful.

During the growth of lettuces, they are tied round, that the exterior leaves may exclude light from the interior, or heart; this becomes white, and eatable, and does not contain a poisonous principle, which is discoverable in the green leaves; plants of endive and secale are grown under earthen covers, and thus become blanched, and fit for food.

The shoots of a potatoe produced in a dark cellar are white, straggling, and differently formed from those

which the plant exhibits under its usual circumstances of growth; the seeds of mustard and cress, germinating in darkness, put forth a crop of a dingy yellow color, instead of a brilliant green; a plot of green grass, perfectly excluded from the light, by a board or stone, becomes of a pale yellow color, and is soon killed; and even when partially excluded from light, by the dense summer foliage of surrounding trees and shrubs, it suffers a similar change of color, and ultimately dies away.

The term *etoilé*, or "star-grown," is applied to vegetables, when their colors have been thus modified or prevented by the exclusion of light.

The effect of light upon the animal creation is no less remarkable; beasts and birds of tropical climates have generally brighter skins, and more vivid-colored plumage, than those of climates farther distant from the equator, and a difference is even observable in the same climates between such as bask in sunshine, and such as prowl in darkness.

Solar light is absolutely essential to the health of man; a strong contrast is presented between the athletic stature and the ruddy cheeks of him who roves on the mountain, and the stunted figure and the pallid features of him who crawls in the mine; in the one case, by light, conjoined with air, food, and exercise, chemical attractions are promoted between the elements of the secretions, to form principles conducive to health; whilst in the other, the absence of such stimulants in due proportions, deranges the vital functions, and disease results.

The vigorous mountaineer, if immured in a dark dungeon, even with a proper supply of food, will soon become more pallid, and yet more unhealthy, than the

miner, who, between the intervals of his subterranean toil, may have the benefit of ascending for a few hours to enjoy the light of day.

The poor inhabitants of gloomy and crowded districts are invariably found with blanched and haggard features, partly on account of the absence of sunlight and pure air; but chiefly, with sorrow be it spoken, on account of their inability, through poverty, to obtain a moderate share of wholesome food.

If we turn from these natural examples of the influence of solar light, to those artificially presented in the chemical laboratory, it is found to affect the brilliancy of dyes, the deposition of crystals, the decomposition of substances, to an extent unheeded in early days of scientific inquiry, and hence the former uncertainty of many operations that are now conducted with precision.

Independently of stimulating the exquisite structure of the eye to the sense of vision, the importance of light is universally manifest, and it displays the wisdom and power of the Creator, who in the beginning said:—

"Let there be light: and there was light."

"And God saw the light that it was good."

"Vegetables, in general, are extremely susceptible of impurities in the air that surrounds them, and very slight modifications in the proportions of its constituents are more or less prejudicial to their growth, especially when they are prevented from the access of light."

In the free and open air of the country, excepting in a very few instances, no matters hurtful to vegetation can be discovered; but the air of large cities and towns is subject to many local contaminations, from several causes, such as the combustion of coal, the smoke of

furnaces, the gases and vapors that are produced, or elicited, during metallurgical operations and other processes of chemical arts and manufactures: "and instead of being surprised at the injury which plants sustain in the atmosphere of a city like London, we should rather wonder that they are not more generally affected by it."

"There is no doubt, however, that plants, like animals, vary in regard to the delicacy of their constitutions, and that some are infinitely more susceptible, not only of changes in the temperature and humidity of the air, than others, but are fatally influenced by the presence of foreign matters which the more hardy tribes resist."

In the immediate vicinity of chemical works, where large quantities of poisonous exhalations are hourly sent forth into the atmosphere, the vital functions of vegetables are strangely deranged or altogether destroyed; the grass, for example, is stunted and brown, the trees are leafless and withered, and we need not wonder at delicate organic structures being thus affected, when we find even the stone and iron-work of adjacent buildings sustain decay and corrosion from the action of the same agents.

An acid vapor called Hydrochloric acid, to denote its consisting of Hydrogen and Chlorine, is probably the most fatal to the life of plants; this is abundantly produced in some chemical manufactories, and causes sterility in the immediate neighborhood. A very simple experiment will prove its baneful effects, as follows.

Select a small geranium or myrtle, growing in a pot, and tie the stem to an upright iron wire, made perfectly bright; set the pot to stand in a tea-saucer, and place this in the middle of a large dinner-plate, containing about half a fluidounce of liquid hydrochloric acid;

then cover this arrangement with a bell-glass, the rim of which will rest upon that of the plate.

Fig. 19.

Liquid hydrochloric acid contains the vapor of the acid dissolved in water, and when exposed to air, it will readily escape; thus in the act of pouring the acid into the plate a dense white fume will be observed; and this will continue to rise and contaminate the air contained in the bell-glass; its poisonous effect upon the plant is manifested in the course of a very short time by the leaves drooping and shriveling; and its corrosive effect upon the iron is shown by the metal losing its polish and becoming tarnished.

Upon removing the plant from this noxious atmosphere, all attempts at its restoration will be in vain; it is killed, and so would an animal be if subjected to similar treatment.

The colors of flowers are curiously affected by acid vapors, as may be proved in the following manner:—place a red rose in the centre of a bunch of dark purple pansies, sufficiently large for the stems to fit the neck of the glass employed at page 68, when introduced in an

inverted position, so that the flowers may hang in the glass with their petals downwards.

Fig. 20.

Place a fragment of sulphur, about the size of a hazel-nut, upon an egg-cup turned bottom upwards, and standing in the middle of a dinner plate; kindle the sulphur by touching it with a glowing coal, and then place the glass containing the flowers over this arrangement, as directed in the last experiment.

The sulphur will continue to burn for a considerable time, and during this combustion, the oxygen of the confined air combines with it, to produce Sulphurous acid vapor, fumes of which will be observed to ascend, and upon coming into contact with the flowers, the red rose will bleach, and the purple pansies will be more or less deprived of color.

If a similar experiment be made with autumnal dahlias of varied colors, they will present a still more striking example of the destruction or modification of their colors by the acid vapors.

In consequence of the existence of the above acid, and other vapors in the atmosphere of large cities, many plants cannot be grown exposed to its influence, and

therefore the following arrangement has been successfully adopted for preventing them from sustaining injury in such localities.

Fig. 21.

The engraving represents a circular wooden box, about fifteen inches in diameter, and six inches deep, lined with sheet-lead, or sheet-zinc, so as to be water-tight; a stratum, about two inches thick, of clean gravel stones, is placed upon the bottom of the lining; then a stratum, about two inches thick, of turfy loam upon the gravel, and the remaining space filled with well-moistened loam; in this various small plants and flower-roots are set in the usual manner; and then covered with a large bell-glass, that rests upon the rim of the box.

The arrangement of the earthy materials in the box closely resembles that of a naturally fertile soil, because the water filtrates by capillary attraction, and remains among the gravel, until the wants of the plants above require it for their support; the water cannot escape by evaporation into the external air, but it saturates that contained in the bell-glass, condenses as drops, and trickles down again to the soil, again to rise as vapor, and again to condense, and thus incessantly circulating,

Again; the same phenomenon is observed when we look at objects beyond the top of a chimney, from which the heated products of a clear burning fire are rising without smoke; and if the chimney belong to a cottage built in a small hollow, with rocks or trees immediately above it, the distortion of their positions is very remarkable.

The examination of this refraction of light belongs to the science of Optics, and not to that of Chemistry; but the reception of heat by the land, which is the cause of the phenomenon, is a legitimate branch of the latter science, and therefore demands our attention.

By the aid of the thermometer, the chemist has discovered that some soils are more easily heated than others, when equally exposed to the rays of the sun; and when they eventually acquire the same degree of temperature, some cool faster than others.

Soils principally consisting of white, and strongly adhesive clay, are not, generally speaking, easily heated, and containing a very considerable amount of water, the heat soon escapes, because it is immediately concerned in producing evaporation;—chalky soils agree with these, as regards heating with difficulty, but as they do not contain a large quantity of water, they do not lose much heat by evaporation.

The chemist has farther ascertained, that an exceedingly dark, or black soil, containing a large quantity of vegetable matter, becomes the most heated, both by the direct rays of the sun, and by warm air, that wafts over its surface from other localities; and that soils containing either much carbonaceous or ferruginous matter, exposed, under equal circumstances, to natural heat, acquire a much higher temperature than pale-colored soils.

"When soils are perfectly dry, those that most readily become heated by the solar rays, likewise cool most rapidly;" but it has been determined by accurate experiment, "that the darkest colored dry soil, (that which contains abundance of animal or vegetable matter, substances which most facilitate the diminution of temperature,) when heated to the same degree, provided it be within the common limits of the effects of solar heat, will cool more slowly than a wet pale soil composed entirely of earthy matter."

A specimen of rich black mould, which presented upon analysis nearly one-fourth its weight of vegetable matter, was exposed for an hour to sunshine, during which time its temperature increased from 65 to 88 degrees: whilst a chalk soil, under the same circumstances, had its temperature increased only to 69 degrees; however, upon removing the mould into the shade, where the temperature was 62 degrees, in half an hour it lost 15 degrees, whereas the chalk similarly situated lost only 4 degrees. Portions of brown fertile soil, and barren clay, were accurately dried, and then artificially heated to 88 degrees; they were afterwards placed in a room at 57 degrees; in the course of half an hour the brown soil lost 9 degrees, but the clay lost only 6 degrees of heat.

Throughout all these experiments, the temperatures were ascertained by a delicate thermometer, and the soils were placed upon equal-sized shallow trays, made of tin plate.

Upon considering the results of these experiments, "Nothing can be more evident than that the general heat of the soil, particularly in Spring, must be of the highest importance to the rising plant. And when the leaves are fully developed, the ground is shaded; and

any injurious influence which in summer might be expected from too great a heat, entirely prevented; so that the temperature of the surface, when bare, and exposed to the rays of the sun, affords at least one indication of the degrees of its fertility; and the thermometer may be sometimes a useful instrument to the purchaser or improver of lands."

The thermometer, although so frequently consulted throughout the Four Seasons, merely denotes the degree of heat that air, water, earth, and other media are capable of imparting, and not the actual quantity of heat therein contained; several experiments can be made concerning this fact, and they will lead to the elucidation of some curious natural phenomena.

Introduce the bulb of a thermometer into one pint of water, and then into four pints of water, drawn at the same time, from the same spring; the temperature of both portions of water will be found alike, although it is evident, upon the slightest reflection, that four times as much heat must be present in the one case as in the other; this the thermometer does not indicate.

To proceed further in this inquiry:—Provide two glass bottles, of equal size and thickness, and resembling each other in every respect as nearly as possible; pour into one of these a pound of Olive oil, and into

Fig. 22.

the other a pound of Water of the same temperature, which, for the sake of illustration, may be 40 degrees.

Provide two similar mercurial thermometers, one of which place in the water, the other in the olive oil, as shown in the engraving.

Carry the bottles, thus prepared, into a room heated to 70 degrees; place them side by side upon a table; allow the air of the room to remain undisturbed by draughts; and in time the oil and the water will gain its temperature; this does not appear remarkable; it is what might be expected;—if, however, the thermometers be inspected from time to time during this proceeding, we find something to excite our attention;—we find that the temperature of the room is acquired by the Oil, in exactly half the time that it is acquired by the Water.

Reverse the conditions of the experiment, by removing the bottles to a cold room, at 40 degrees, for example, and it will be found that the Oil will acquire such temperature, or cool, in exactly half the time that the Water will require to cool.

What inference is to be drawn from these experiments? Why, in the first place, that the oil requires less heat than the water to raise it to the thermometric temperature of 70 degrees; and in the second place, that it parts with such heat more easily than the water.

The chemist denotes these results by a technical term that conveys a direct and concise meaning; and technical terms facilitate inquiry when they are understood, but impede it if employed without explanation; the Oil required less heat than the Water, and parted from it with the greatest readiness, therefore the chemist says, that the Capacity of Oil for heat is less than that of

Water, exactly as we should say that the capacity of one mind for the reception and retention of knowledge, was less than that of another.

In fact the oil acquired and lost heat with twice the facility of the Water; and if, for the sake of example, the Capacity of the Oil be called fifty, that of the Water is one hundred; or yet more simply,—the Capacity of oil is half that of water.

A very simple and decisive experiment will prove, that equal weights of Oil and of Water, although at the same thermometric temperature, do not contain the same amount of heat; and for the performance of this, the following preparations are required.

Two cylindrical canisters, of tin-plate, each of these being six inches in height, two inches and a half in diameter, and having a cover with a knob in its centre, and a perforation near that, about three-quarters of an inch in diameter; these covers must fit very tight, or have small catches, so that upon holding them by their knobs, the canisters will not fall away, but will require considerable force to effect a separation.

Two cylinders of tin plate, in height equal to that of the canisters, but in diameter about an eighth of an inch greater, and open at each of their ends, so that the canisters may easily slide through them.

Two earthenware flower-pots, alike in shape and size, in depth equal to the height of the cylinders, but in diameter at bottom about three-quarters of an inch greater than them; two large hyacinth glasses, resembling each other in shape and size as nearly as possible; and lastly, two small mercurial thermometers, similarly graduated, and with bulbs small enough to enter the apertures in the covers of the canisters.

Suspend a pair of common scales from any convenient and steady support, and in each of its pans place a canister without its cover; they will probably not balance each other, therefore small shot and sand must be added to the scale-pan containing the lightest of the two, until an equilibrium is effected.

Pour olive oil into one canister, until it is filled within half an inch of its rim; then pour water into the other, until it is sufficient to balance the oil; thus equal weights of the two liquids are obtained; the canisters are then to be removed from the scale-pans, and firmly closed with their respective covers, and the thermometers introduced through their respective apertures.

Place the canisters to stand upright in a saucepan, sufficiently deep and narrow to prevent them falling upon one side or the other; then pour water into this, until the canisters are rather more than half immersed; lastly, place the saucepan over a clear glowing fire, that the water may boil.

This it will probably do, at or near 212 degrees; but whatever temperature a thermometer may indicate, as the boiling point, of course it will be imparted to the canisters; their contents will become equally heated, and the thermometers will be equally affected: this is the condition to be fulfilled.

Whilst it is in progress, a few more arrangements can be made:—select two pieces of wood, each of these being two inches in length, and sufficiently square to remain firm, when thrust half way into each of the small circular apertures of the flower-pots; then place each of these to stand upon a deep cup, or jar.

Fold about two pound of clean ice in a flannel, and beat it with a mallet, until the ice is broken into pieces

about the size of ordinary hail-stones, and, if necessary, let it drain in a sieve.

Thrust a crumpled sheet of thin paper into one end of each cylinder, to form a temporary stopper; then place each with this end uppermost, to stand in the centre of each flower-pot; and carefully fill the space between the exterior of each cylinder and the interior of each flower-pot, with the powdered ice; this is most easily done, by dropping in a small portion at a time from a wooden spoon.

The ice is prevented from entering the interiors of the cylinders by the paper stoppers; these are now to be removed, and each flower-pot lifted, to stand upon the top of each hyacinth glass.

If the water boil in the saucepan, remove it from the fire; protect the hands with thick woolen gloves, and lift out each heated canister at the same time, holding one in the right hand and the other in the left; then drop each at the same moment into each cylinder, and immediately lift up each cylinder completely away, that the ice may simultaneously come in contact with each canister.

In this arrangement, the canisters are supported one inch above the apertures in the flower-pots, by the plugs of wood, and these being square, they prevent the ice from falling through, whilst they readily allow the water resulting from its thawing to pass, and direct it into the respective hyacinth glasses.

When removed from the boiling water in the saucepan, the Water and the Oil were of the same thermometric temperature; and if they contain the same amount of heat, if they have the same Capacity for heat, then, in cooling down to the same degree, they should most cer-

tainly thaw equal quantities of ice, and equal quantities of water should flow into the glasses.

But the Capacity of Water for heat is Double that of the Oil, as already stated, and as now strikingly proved; for upon the thermometers indicating the same temperature in both liquids, it will be found that the Water has thawed twice as much ice as the Oil, and accordingly the hyacinth glass that supports the flower-pot holding the Water-canister, will receive twice as much water as that which supports the flower-pot holding the Oil-canister.

The annexed engraving shows this result, and may aid the whole description that has been given of the method of performing this remarkable experiment.

Fig. 23.

By a similar proceeding with other liquids, conducted with extreme precision, and accurate apparatus, the chemist arrives at the conclusion that Water possesses the greatest capacity for heat, and the least sensibility to heat of any substance with which he is acquainted; the extraordinary, the important consequences of this

fact throughout nature, will be apparent at a future Season.

Solids, liquids, and aëriform substances, though of the same thermometric temperature, have different capacities for heat; and these are most singularly affected by changing their physical state of density.

Thus, at common temperatures, if a given bulk of Water weigh 1000 parts, the same bulk of Lead will weigh 11,350 parts; if this be violently compressed by machinery, the individual particles of the metal are thrust, or packed into less bulk than they originally occupied, the lead becomes more compact or dense; and now, if its weight be compared with that of an equal bulk of water, it may be found perhaps increased to 11,360 parts, or, in other words, the lead has increased in density.

Lead, in common with other substances, contains a certain amount of heat, or has a certain capacity for heat; and if a strip of the metal, placed on an anvil, be suddenly and forcibly beaten with a hammer, its density is increased, but its capacity for heat is diminished; the particles of the metal being compacted into a smaller space, have not room for all the original heat; some, therefore, escapes, and warms the lead, to a degree painful to the hands; indeed, it will immediately kindle a small piece of phosphorus.

A dextrous blacksmith will place the point of a soft iron horse-shoe nail upon an anvil, and strike it only two violent blows with a hammer, and the point will instantly become red-hot, and inflame a sulphur match; thus he generally obtained fire, before the introduction of Lucifer matches.

In further elucidation of these curious matters,—

which at first sight may appear to have no connection with the chemical phenomena of the Four Seasons;—a piece of sponge may represent the metal; the sponge has a certain capacity for holding water, the same as the metal has a certain capacity for holding heat; when the sponge is squeezed, its particles are brought closer together; it has less capacity for holding water, and accordingly some will run out; so the metal, when struck, has its particles more closely compacted, and therefore less capacity for holding heat, and some must escape.

Change of density in liquids is also attended with change in their capacities for heat, and the chemist can furnish experimental illustrations of this phenomenon;—provide an apparatus resembling the annexed engraving.

Fig. 24.

It is a glass tube, twelve or fourteen inches long, half an inch diameter, closed at one end, and enlarged at the other into two bulbs, about three inches diameter, connected by a neck the same size as the tube; the bulb farthest from it has a mouth, provided with an accurately-fitted stopper, slightly touched on its ground part with pomatum, for a reason already described.

Remove the stopper, and holding the apparatus upright by the bulb to which the stopper belongs, pour in water until the tube and lower bulb are filled; then pour in alcohol, until the upper bulb and its mouth are filled; carefully insert the stopper, and wipe away the little quantity of alcohol that will flow over.

In this arrangement, the water, being the heaviest

liquid, will remain below, and distinct from the lighter alcohol; the two liquids are prevented from mixing rapidly, by the narrow neck between the bulbs, and they are both of the same thermometric temperature.

Place the palm of the hand over the stopper, grasp it and the bulb, and invert the apparatus, that the tube may now stand perpendicularly; and in this position the heavy water will fall through the light spirit, or *vice versa;* the tube will not appear full as it was originally, and the bulbs will become sensibly warm.

Why is the tube deficient of its contents, for the ground stopper has prevented any portion of liquid from escaping, and why do the bulbs feel warm?

Because the light alcohol, by combining with the water has its density increased, it occupies a smaller space than at first, and, like the solid lead, has its capacity for heat diminished; a portion therefore escapes, and affects the hand.

These experiments are preliminary to others upon the atmosphere, which most concerns our present inquiry; and we shall find that changes in its density, by condensation and refraction, produce changes in its temperature, elevation in one case, depression in the other.

All aëriform substances admit of more sudden condensation and rarefaction than either solids or liquids, and therefore experiments, upon such highly attenuated and often invisible forms of matter, are not only extraordinary, but instructive.

The annexed sketch represents an apparatus for proving that the condensation of air compels it to part with heat.

Fig. 25.

It consists of a well-annealed, and perfectly cylindrical glass tube, fourteen inches long, a quarter of an inch thick, and rather more than a quarter of an inch internal diameter, containing air; one end of this tube is closed with resinous cement, which likewise secures a brass cap, terminating in a ball, about one inch and a half in diameter, whilst the other end of the tube is open, but its circumference bound with a brass band, about two inches broad, to prevent it from being accidentally chipped.

The other part of the sketch represents a rod of well-tempered steel, about one inch longer than the glass tube, but rather smaller than the bore, for about twelve inches; one end of this rod is firmly screwed into a flat brass knob, about one inch in diameter, whilst the other end is enlarged and closely packed with oiled leather, to form a piston, which accurately fits the tube; the end of the piston has a small hook, or it is slightly cupped, to hold a fragment of perfectly dry German tinder, about the size of half a pea.

Insert the piston with the tinder into the glass tube; place the brass knob upon a solid table, that the brass ball may be uppermost; grasp this with the right hand, steady the tube with the left, then with one sudden and powerful jerk, thrust the tube down as far as practicable; a vivid flash of light will instantaneously appear; and upon quickly withdrawing the piston, the tinder will be found burning as perfectly as though it had been kindled at a common flame.

Why is this? Because the sudden compression, condensation, or increase of the density of the air in the tube, diminished its capacity for heat, or, in other words, the sudden thrust beat the heat from the air, as the sudden

valve being made to open upwards, the air in the receiver, in consequence of its extraordinary property of elasticity, or property of self-adjustment to the circumstances under which it is placed, immediately expands, passes in the direction of the perpendicular and horizontal feathered darts, lifts the valve and fills the barrel, as indicated by the two double-barbed darts in the annexed figure.

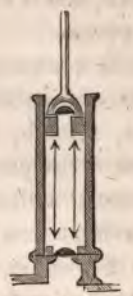

Fig. 27.

By thus expanding, rarefying, or diminishing, in density, the heat originally contained in the air, is, of course, more weakly diffused throughout such enlarged volume; it is not so concentrated around the thermometer, and this instrument will indicate a slight depression of temperature.

By thrusting down the piston, its valve will open and permit the air, indicated by the two double-barbed darts, to escape, and fill the barrel as formerly indicated by the two featherless darts; whilst the valve in the chamber firmly closes, and prevents its return into the receiver.

By raising the piston a second time, a second call is made upon the air in the receiver: it again expands, lifts the valve, and fills the barrel; its density is now less than

before, its heat is more diffused over an equal space, and the thermometer will again denote cold; and by thus proceeding, repeated calls are made upon the air in the receiver to supply the repeated losses of that from the barrel, until at length it is exhausted, and the thermometer will fall several degrees.

It will now be impossible to lift the receiver from the plate, because it is firmly held on by the pressure of the external atmosphere, which amounts to about fifteen pounds upon each square inch of surface; this pressure manifests the endeavor of the external atmosphere to enter and to restore the equilibrium that has been disturbed.

By removing the small screw that is placed under the valve chamber, the external air will immediately enter, the equilibrium will be restored, the density of the air in the receiver will be the same as it was, and the thermometer will slowly rise to its original degree.

During the ascents and descents of the piston in this experiment, another phenomenon will be observed, namely, the interior of the receiver appears as though it were filled with mist; this is really the case, and for the following reason.

Air invariably contains the vapor of water, and to raise such vapor, and to retain it, a certain amount of heat is necessary. The air included by the receiver contained the vapor of water, invisibly maintained throughout its volume by heat; but upon being suddenly compelled to expand, the heat is as suddenly diffused throughout such expanded volume: the vapor thus chilled or robbed of heat, is converted into minute drops of water, and forms an artificial mist.

This experiment accordingly furnishes the chemist with an explanation of the formation of a natural mist, the invisible heated watery vapor present in the air becoming visible, minute drops of water, when its temperature falls, either by sudden local rarefaction of the air, or by coming in contact with cold surfaces of the earth and waters.

To impress these curious and important matters upon the mind of the young student of Nature, take the following example: —Suppose a cubic foot of air contain a certain amount of heat, equally diffused throughout its elementary and compound constituents, and capable of affecting the thermometer to a given degree; if this volume of air be compressed to one-tenth of a cubic foot, of course there will be ten times as much heat concentrated into that tenth as there was, and the thermometer would indicate a rise of temperature.

On the other hand, suppose the cubic foot of air to be expanded to ten cubic feet, the heat would be so diffused throughout such volume, that the thermometer would indicate depression of temperature, or, in other words, the air would feel cold.

These experiments of the laboratory furnish the chemist with a key to the explanation of natural phenomena; an enormous store of heat is contained in the atmosphere; but this medium is not of uniform density from the earth to its own confines; those portions that are directly incumbent upon the earth are most dense, because they bear the weight of superincumbent portions; as, to use a very humble simile, the hay at the lower part of a rick bears the weight of that above, and is therefore more compact and dense; or it may be conveyed by the accompanying engraving, the gradual shading of which

denotes the gradual diminution in the density of the atmosphere in proportion to its altitude.

Fig. 28.

The compression of the lower, by the upper portion of the atmosphere, alters its capacity for heat, as it was altered by the compression of the piston, in the experiment so recently described, and accordingly heat escapes from the atmosphere in quantity suited to time and season for the welfare of the animated creation.

If we ascend a lofty mountain, and thus approach many hundred feet nearer to the sun than we were in a valley, we might expect to find the temperature considerably warmer; but the contrary is the case. When we left the valley, it was glowing under the heat of the summer sun, we can see it still glowing, and though we are nearer the sun on the mountain summit, the air is intensely cold; what reason can be assigned for this? The chemist submits the following:—It has been already stated that the sun does not heat the transparent air; and at the elevation just mentioned, it is greatly rarefied or comparatively free from pressure; the heat that it has derived from contact with the warm earth is widely diffused, and in a given volume of air on the mountain summit, there is not the actual heat that exists in a similar volume in the valley.

Again; warm air in ascending from the valley expands,

and remotion of heat, or, in other words, cold is produced, and frequently to such an extent that the watery vapor of the air condenses in clouds, which, when surcharged, deliver rain, or it congeals as snow, and clothes the mountain summit.

Air, in rising from the level of the sea, becomes nearly one degree colder for the first two hundred feet of ascent, and altogether about fifty degrees colder in rising fifteen thousand feet; thus, water would freeze at this elevation even near the equator, where the temperature of the low plains is at least eighty degrees; this is the reason why the summits of lofty mountains are covered with perpetual snow, and the height at which it occurs is called the "snow line," or "line of perpetual congelation."

The Andes present a magnificent illustration of these phenomena attendant upon the varying capacity of air for heat; placed nearly under the equator, they tower from parching sands; about their middle height the climate is temperate; their summits are crowned with unchanging snow, and these ranges of temperature are always distinct; the hot winds from below, if they ascend, become gradually cooled by expansion, and if by any force of the blast the cold air be driven downwards, it is condensed, and rendered warmer in its fall.

How grand, how beautiful, how harmonious, are these adjustments and balancings of the Almighty Hand, who "made the weight for the winds, and weighed out the waters by measure!" how eminently calculated they are to inspire us with emotions of admiration and gratitude towards the Author of our being!

He has ordained the level earth to be the chief dwelling-place of mankind, and commanded the air directly

incumbent upon it to be of the just weight or density, and to contain the due amount of heat which vitality requires for the proper maintenance of its manifold recondite functions; whilst on greater elevations, which are but thinly peopled, or on mountain summits, which are but rarely visited, these wondrous agents, air and heat, are rare and feeble, because they are not required in abundance and power for the support of life!

Exploring and investigating throughout the treasures of the Creation, we become more and more impressed that it is founded upon the most miraculous scale of beneficence; that bounteous gifts are not indiscriminately scattered where they would be useless to organic beings, but are abundantly presented where required for their manifold wants.

Great, inexpressibly great, is the delight in thus being permitted to follow the marvelous works of the Creator, to trace the unbounded power and transcendent goodness which are displayed alike in the mightiest and the lowliest parts of the terrestrial world.

"In the heavens hath He set a tabernacle for the sun, which is as a bridegroom coming out of his chamber, and rejoiceth as a strong man to run a race; his going forth is from the end of heaven, and his circuit unto the ends of it, and there is nothing hid from the heat thereof."

In the splendid poetical images of the above passage, are set forth the beauty, power, glory, and genial effects of solar light and heat during an unclouded day; let us trace the Hand by which these are all directed to work together for our good.

During the brilliant zenith of summer, even in torrid climes, although the heat of the sun impinges upon the

earth, with vast and continued power, its degree is so miraculously adjusted and restrained by Providence, that it never attains sufficient intensity to cause the destruction of organic bodies by combustion. Nay more, the chemist, after all his extensive researches throughout the varied objects of the Creation, can find neither a single element nor a single compound in a native state which is capable of inflaming by solar heat.

If the heat of the sun were not thus miraculously adjusted, by the power and goodness of God, to the earth and its productions; if the earth were capable of receiving and retaining all the heat that is constantly sent forth from the sun; if the air were capable of being heated by conduction, the increase of the temperature of the globe instead of being, as now, probably only one degree in one thousand years, would be upwards of three hundred degrees in a single year; and, above all, if the whole atmosphere were to sustain sudden condensation of its volume, the temperature would instantly exceed that of red-hot iron.

Thus all living things would perish; the waters would be dried up, and the earth, by the accumulated heat, would ultimately "pass away."

Considering the elements and constituent parts of which this terraqueous globe is composed, how slight a disturbance in the present harmony and order of its adjustments would cause its instantaneous destruction!

These are facts which become apparent during the pursuit of science, and like all others so discovered by man, they emanate from "The Fountain of All Truth."

Pure science, therefore, corroborates the testimony of Scripture, which recounts the first revolutions of The Creation, and which equally foretells the last.

Scripture recounts, "That by the word of God, the heavens were of old, and the earth, standing out of the water, and in the water:

"Whereby the world that then was, being overflowed with water, perished."

Scripture foretells, "But the heavens and the earth, which are now, by the same word are kept in store, reserved unto fire against the day of judgment and perdition of ungodly men.

"In the which the heavens shall pass away with a great noise, and the elements shall melt with fervent heat, the earth also, and the works that are therein, shall be burned up."

"Wisdom is the breath of the power of God, and a pure influence flowing from the glory of the Almighty," and concerning His manifold, wondrous, and perfect works, it is gradually permitted to man, through the proper and chastened exercise of his noblest faculties, during the short period of his sojourn here upon earth, that he may be led to a sincere and grateful appreciation of the power and goodness of God; and this will blend in perfect harmony with the humble and devout confession of an implicit faith, and constant obedience, as commanded in His Revealed Will.

Unless a firm belief of another and far higher stage of existence be deeply fixed in the mind of man, to uphold him during his present state of progress and trial, his science is vain,—his philosophy is false.

As intricate derangements of the elements of nutritious food, cause its transition into deadly compounds by the refined experiments of the chemist, so do subtle perversions of the elementary truths of pure science yield moral poisons by the cunning of the sophist; but the first shrinks

back with fear and dread, lest his discovery should be wilfully or accidentally misapplied, whilst the second stands forth with presumption and arrogance, and prides himself upon the exhibition of his morbid skill in turning good gifts to bad purposes.

It is accordingly the duty of the teacher of science, to "put on the whole armor of God; to stand girt about with Truth;" and thus, not only instruct, but guard the mind of the young disciple entrusted to his care, by the Divine admonitions which irradiate the invincible "shield of Faith, wherewith he shall be able to quench all the fiery darts of the wicked."

"Prove all things; hold fast that which is good."

"Let no man spoil you through philosophy."

"Be not carried about with divers and strange doctrines."

"Perverse disputings of men of corrupt minds, and destitute of the truth, supposing that gain is godliness, from such withdraw thyself."

"And this I say, lest any man should beguile you with enticing words."

The foregoing remarks were called forth during an early stage of our investigation of the beautiful phenomena consequent upon the miraculous adjustment of the temperature of the solar rays to the earth and its productions; let us now resume this interesting subject.

During the most intense heat of Summer, the atmosphere is never anhydrous, or devoid of watery vapor, though frequently so desiccated, that the animal and vegetable creation droop beneath its parching influence; then, mark the power and goodness of the Almighty Hand, that is beneficially extended for their relief.

The invisible watery vapor is commanded from its

wide aërial expanse in other localities, and gathered into opaque clouds; these float between the sun and the earth, and act as veils in preventing the direct transmission of solar heat.

The clouds thus permit the earth to lower in temperature, and, in so doing, they either gain sufficient heat for their own dispersion as invisible vapor, again to collect, and to perform the same genial office in other suffering districts, or they fully complete the wondrous work of present relief, by relinquishing their waters in showers.

These are eagerly imbibed by the arid earth and its productions, whose leaves and flowers immediately send forth their delicious fragrance and perfume in grateful return for such miraculous and salutary aid.

This phenomenon, upon close examination, appears to depend upon the functions of plants being suddenly excited by water to the elaboration of aromatic principles, although its exact theory is still unknown; but the peculiar odor which is emitted even by barren earth, after a summer shower, is fully proved to depend upon the combination of water with the aluminous and ferruginous matters which are present in the soil.

Neither pure alumina, nor oxide of iron, emit odor when separately watered, but it immediately becomes perceptible when they are mingled together, and in such condition they are naturally found in soils.

The water of the shower, having yielded refreshment to the earth, is again destined to ascend as vapor into the atmosphere, under the agency of heat derived from the earth.

The delightful coolness of the earth, after a summer shower, induces man and animals to venture forth from

production of vapor will be taken from a bottle of wine placed in the vessel, a considerable diminution of temperature is obtained.

To remain in wet clothes, is proverbially dangerous, especially when exposed to a draught of air, for evaporation immediately takes place with such rapidity, that the animal heat of the body is lowered below its natural standard, and rendered injurious to vitality; if, however, exercise be taken, there is less danger, because the action of the muscles incites the evolution of animal heat, in proportion as it is demanded by evaporation.

The natural temperature of the human body is between 96 and 98 degrees; but when we take very active exercise, or when we are exposed to a great degree of heat, there is a tendency to a rise of temperature, which is conducive to health; and the most injurious effects would ensue, if it were not for perspiration, which withdraws heat from the body, and cools it down to the healthy standard; if this perspiration be checked in its escape, by air-tight, or water-proof clothing, the most serious and occasionally fatal consequences may ensue.

By merely placing the hand on a cold, dry plate of glass, or in a bell-glass, the watery vapor which escapes as perspiration will condense, and immediately become perceptible, as it was found to do from the surfaces of leaves in the experiment at page 85.

Upon applying a cambric handkerchief to the perspiring brow, great relief and coolness are immediately experienced, because the fine fibres of the cambric have an extremely strong capillary attraction for moisture, and a good conducting power as regards heat; thus by rapidly

abstracting both moisture and heat from the skin, the refreshing sensation of coldness is produced.

The case is different with a cotton handkerchief, because its coarse fibres have neither strong capillary attraction nor good conducting power; and its application to the skin produces a sensation of heat.

The cold produced by evaporation can be immediately detected by several simple experiments; for example, let the bulb of a thermometer be smoothly covered with a piece of fine cambric; and by keeping this constantly wetted during the time that the thermometer is suspended in a draught of air, or by blowing upon it from a pair of bellows, the thermometric liquid, be it either mercury or spirit, will descend, and indicate cold.

Fig. 29.

The above engraving represents a glass tube, about one-quarter of an inch internal diameter, and ten inches long, having at one extremity a bulb one inch and a half diameter, and at the other, which is bent like a shepherd's crook, another similar bulb, with a small short neck; pure water is introduced through this, until the plain bulb is about half filled; and then, by cautiously holding it over the flame of a spirit-lamp, the water will soon boil; its steam will expel all the air originally contained in the instrument; and when this happens, the orifice of the neck is suddenly melted by the flame of another lamp.

The instrument is thus finished, and by shaking it, the water will fall through the tube from one bulb to the other, not with a gurgling sound, but with a sharp, click-

ing noise, because there is no air to resist its rapid fall, or to act as a spring against its immediate contact with the glass; or, in other terms, the water is in vacuo as regards the absence of air, and only subject to the pressure of its own vapor.

If the instrument be now held slightly inclined, as shown in the engraving, with the hand grasping the plain bulb, the expansion of the vapor will force nearly all the water into the other; the moment after this has ensued, it will be succeeded by a rapid bubbling, and the hand will then experience a sensation of cold, because heat is suddenly withdrawn from it to enable the small portion of water adhering to the bulb to assume the state of vapor.

The empty bulb of the instrument may be now placed in a mixture of equal parts of finely-powdered ice and salt, contained in a pint finger-glass, and covered with a glass shade, for the performance of another experiment, the rationale of which is as follows:

Fig. 30.

The mixture of ice and salt produces a very low temperature, (for a reason to be explained hereafter;) it immediately condenses the vapor in the bulb into

water, and afterwards solidifies it into ice; but the water contained in the upper bulb immediately emits a portion of vapor to supply the loss below; this in turn is condensed and solidified, fresh vapor is again emitted from above, and so on, until the water by these successive calls has lost so much heat that it can no longer remain liquid, but is forced to become solid or to freeze, although at so great a distance from the source of cold.

Hence the instrument is known to the chemist by the name of "Cryophorus, or Ice-bearer;" and when the phenomenon has ensued, the bell-glass should be lifted off, and the instrument immediately removed, (for a reason to be given hereafter,) that the ice may slowly thaw; and it will present the same phenomenon, upon immersion in a freezing mixture at any future time, even in the height of summer, if covered with the bell-glass to prevent the direct access of warm air to the upper bulb.

It illustrates the curious fact, that water may be frozen by the cold produced during its own evaporation; but the more particular consideration of the wonderful natural law which presides over the transition of water into ice, will demand our attention, during our examination of the chemical phenomena of Winter.

From this experiment, and from the table at p. 130, it is evident that water is capable of evaporating at very low temperatures; and on account of the immense quantity which is spread over the globe, many extraordinary and important changes in the atmosphere are doubtless caused by this phenomenon.

Accurate experiments appear to justify the conclusion, that the annual evaporation of water averages thirty inches, meaning, that the vapor, if re-converted into water, would cover the surface from which it

ascended, to a depth of thirty inches; then the surface of all the waters of the globe being assumed at one hundred and twenty-eight millions of geographical miles, nearly sixty thousand cubic miles of water would be annually changed into vapor.

The presence of watery vapor in the air is indicated by its condensation upon a cold surface; as for example, on that of a decanter, containing water drawn from a deep spring; and yet more satisfactorily, by the action of certain substances which have a powerful chemical attraction for water; Pearl-ash, or Carbonate of potash, is one of these; if an ounce of it be carefully weighed, and left in the scale for a few hours, even during the driest weather, it will be observed to preponderate, on account of attracting water, and in the course of some days, although thoroughly protected from rain, the solid pearl-ash will change into a thick oily liquid; this is only an extremely strong solution of the substance in water attracted from the atmosphere; Pearl-ash is accordingly called a Hygrometric, and Deliquescent compound.

It is popularly known, that clothes wetted with sea-water will seldom become perfectly dry; this is because sea-water contains chloride of sodium and chloride of magnesium, the former being hygrometric, and the latter deliquescent, so that in place of the clothes drying perfectly, they absorb water from the air, with greater or less avidity according to the temperature.

In very hot and dry weather, a white crust appears on clothes that have been wetted with sea-water; this is the saline matter, deposited by the evaporation, but it will soon disappear or dissolve upon the approach of damp weather.

Hence a sea-weed forms a natural hygroscope, the

alternate appearance and disappearance of its saline matter, its crispness, and softness, indicating changes in the dryness and dampness of the weather.

If a large sponge be dipped in sea-water, and then squeezed almost dry, upon being accurately balanced in a pair of scales suspended from a steady support, it will be found to preponderate, or to ascend, according to the relative dampness or dryness of the weather.

Fig. 31.

It by no means follows that hygrometric substances should contain deliquescent salts, for many do not, yet their physical, fibrous, or capillary structure is such as to enable them to absorb water, mechanically, and thus become affected in form; this is the case with the beard of the wild oat; it is commonly placed in a small circular frame at the top of the household "weather-glass," and by twisting and untwisting, during atmospherical changes in the local quantity of watery vapor, carries round a piece of straw as an index to "Dry" and "Moist."

"The weather-house" is a very ingenious and accurate hygroscope, well known to most husbandmen; it consists of a small model of a building, having two archways, separated by an intervening pier, or column, which does not quite touch the floor; one end of a piece of harp, or violin string, is secured to the roof, and passing

down the pier, carries at the other end a cross-wire, an extremity of which proceeds into the centre of each of the archways, supporting on the one hand a male, and on the other a female figure.

The harp, or violin string, is then gently turned, that the figures may be parallel with the archways; and as it is a hygrometric substance like the beard of the wild oat, it will twist or untwist according to the dryness or dampness of the air, and cause in the former case the cross wire to turn, that the female figure may come beyond its arch, whilst in the latter case, the male figure will advance.

This "weather-house," and another similar contrivance equally well known, as "the monk and cowl," to indicate changes in the humidity and dryness of the air, should be kept in a hall or passage, where the natural temperature is unaffected by the artificial heat of a fire; if they be placed in a warm dry room, the female figure will be always beyond its arch, and the cowl always thrown back from the head of the figure of the monk.

Although the foregoing, and many other, substances are commonly called "Hygrometric," they are more correctly denoted by the term "Hygroscopic," since they do not measure, they only show, the presence of watery vapor in the air. The true "Hygrometer" will engage our attention when considering the chemical phenomena of Autumn.

The atmosphere being continually in motion from the disturbance of its equilibrium by heat, performs a most important part in the economy of Nature, the tropical regions are refreshed, and their temperature prevented from attaining a degree insupportable to the human frame by the cool currents that arrive from the polar regions;

and, on the other hand, these have the severity of their cold modified by the arrival of warmer gales.

Tropical islands and coasts are subject to the refreshing agency of sea and land breezes; these result from the motion of the atmosphere in seeking to restore the disturbance of equilibrium that it has sustained by heat.

The chemist offers the following explanation of these phenomena:—the solar beams are incapable of elevating the temperature of the transparent water of the ocean, or the transparent volume of the atmosphere, but they heat the surface of the opaque earth, as already stated, with great facility; therefore an island exposed to the tropical sun, has its soil greatly elevated in temperature, and communicating heat to the air, a strong ascending current is produced, whilst other portions of air from the cooler surface of the ocean, immediately glide inland to restore the equilibrium, and this constitutes the sea-breeze.

During the night, the surface of the island, no longer subject to the direct influence of the sun, becomes much cooler than the superincumbent air, and causes it to contract in volume, to become heavier; therefore it sinks down, and spreads on all sides, producing the land breeze; this is frequently loaded with unhealthy exhalations from decomposing vegetation, whilst the sea breeze is salubrious and fresh.

Although water is so essential to the growth of vegetables, if it remain in them after they are removed from the soil, or deprived of vitality, it is the most active agent in causing their decay and corruption; and in order to preserve them, they must be dried to a very great extent, but always short of that which would cause a new arrangement of their elements or decomposition.

The atmosphere, on account of its strong attraction for water, and its miraculous adjustment of temperature, is a grand natural agent for effecting this desiccation generally, and of the hay and corn harvest particularly.

The long green grass, as it falls beneath the sythe of the mower, is extremely succulent or abundant in water, and if collected into heaps, it would soon putrefy and become worthless.

The careful and provident husbandman, knowing this fact from experience, not only chooses the most settled weather for the commencement of the hay-harvest, but engages a troop of active work-people, to follow directly in the track of the mowers, and to shake and turn the green swathes about, that all may be quickly and effectually dried in the warm air; and when this is properly done, the hay may be stacked without danger; it is no longer prone to rot, but remains a fragrant nutritious store of provender against the "time of need."

The very best sun-dried hay generally contains upon the average from fourteen to fifteen per cent. of water; but this quantity does not interfere with its preservation.

In this country, the weather is not always propitious during the hay-harvest; heavy showers are very frequent; these saturate the newly-mown grass, and dissolve out a considerable portion of nutritious matter, and load the air with so much vapor, that no drying can ensue until the return of fine days.

It is an old saying, that "hills draw the wet," or "hills draw the clouds," but they have no inherent or particular attraction in this respect; they are only surfaces of the earth, projecting above its common level, and thus being nearest to the clouds, they soonest receive the rain, and often in such abundance, that it swells into floods,

which, descending on the recently-mown low lands, suddenly inundate them, and carry off the hay.

This disaster is not only confined to the immediate districts in which it first occurred, but is very frequently extended to others many miles remote, as the flood rolls onward, to seek its level; every possible means are therefore taken by the husbandman, for preventing the total loss of the valued crops, upon which his hopes of future prosperity were anxiously founded; hurdles and tall stakes are thickly set upright in the course of the flood, ropes and chains drawn across it wherever practicable; all hands are active with rakes, and these contrivances, aided by fences, hedgerows, and plantations, are sometimes effectual in arresting or collecting a portion of the hay; it then requires fair weather for drying, but is found to be greatly damaged, not only by the solvent power of the water, but by the sandy and earthy matters deposited from the mud.

During the anxiety and hurry consequent upon unpropitious weather, the husbandman is often compelled to stack the hay whilst it is damp; but he generally takes the precaution of leaving one or more vacant spaces, reaching from the bottom to the top of the stack, to admit air, and to allow of moisture evaporating from the hay; and thus the chance of its heating or firing is greatly if not effectually prevented.

When a stack consisting of many tons of hay is burned, either by natural causes, or by the accidental contact of household fire, or by the wilful application of the torch of an incendiary, the only remaining traces of the originally valuable property, are a few pounds of apparently worthless vitrified ashes.—How are we to account for this?

On chemical principles:—the chemist, during his manifold researches, examines the elements and compounds which are required for the growth of "the grass of the field;" and he proves, that unless the earth Silica, and the alkali Potash, be duly present in the soil, it will not yield a full crop; he discovers that the minute terminal fibres of the roots of every kind of grass, during vitality, have the extraordinary power of withdrawing these two inorganic compounds from the soil, and of elaborating them as clothing for their own organic structures; and that when the vitality of the grass is destroyed by the sythe of the mower, the silica and the potash still remain in the dead and withered hay.

The chemist prepares a mixture, containing certain weights of Silica and Potash; he heats this in a fierce fire; he finds these two substances combine, and melt into a liquid, which upon cooling becomes solid Glass.

This curious experimental fact enables the chemist to explain, that during the combustion of the hay-stack, the elements, Oxygen, Hydrogen, and Carbon, constituting its actual organic matter, escaped as flame and smoke, whilst the compounds Silica and Potash, being inorganic and fixed, were incited by the intense heat to combine and produce Glass, similar to that obtained in the operations of the laboratory.

The destruction of the valuable stack by fire, may at first sight be regarded as a loss, for which no compensation is made by the curious discovery concerning its vitrified ashes; but after the grief of the moment has passed, and the husbandman can reason calmly, he finds that the catastrophe teaches him an important lesson.

In plain terms, it places before him, directly and pal-

pably, the inorganic substances which every kind of grass requires for its clothing; it leads him to reason upon this, and to mingle silica and potash with soils in which they are not naturally abundant; and thus, under Providence, the next consignment of seed to the earth, may germinate and flourish in greater perfection and luxuriance, and yield at the season of maturity a greater and more valuable harvest than even that of which a portion was destroyed.

The chemist proves the same facts to be even more importantly applicable, as regards the growth of corn, for he discovers the beautifully smooth and polished clothing of its straw, consists of silica naturally withdrawn from the soil, in company with potash, and elaborated by the wonderful vital functions of the plant.

This silica, by its flinty hardness, and its insolubility in water, shields the soft organic tissue of the straw from the depredations of insects, and protects it from the solvent action of rain; it likewise confers strength and elasticity upon the tissue which alone would form a weak and fragile stem, enables it to support the weight of the full ear, permits it to bend beneath the passing blast, and causes it to recover an erect position in the tranquil air, that its maturity may be promoted by the rays of the glowing sun.

Silica is nearly absent from the ear of corn, but the earthy compounds already mentioned as phosphate of lime and phosphate of magnesia, are invariably present in considerable proportion; and if these substances, together with potash, do not naturally occur in soils intended for the growth of corn, they must be artificially added by the agriculturist, or a full harvest can never be obtained.

"Sandy and calcareous soils are generally deficient in potash, and are unfruitful in grasses and corn; but turneps and other plants which require but little of such compound, will thrive exceedingly well; on the other hand, clayey, or argillaceous soils, are very abundant in potash, and accordingly are fruitful in grasses and corn."

The agriculturist is aware that successive crops of wheat cannot be advantageously grown upon the same soil; the chemist points out the reason of this, namely, that the potash of the soil becomes exhausted; and he proves that wheat crops, of all others, are the most exhausting; for example, one hundred pounds of wheat-straw, when burned, will generally yield fifteen pounds of ash or cinder; whilst the same weight of barley straw will yield but nine pounds, and of oat straw only four pounds. The growth of beans and of beet demands none of the earthy compounds which are so imperatively requisite for that of wheat and other grain.

The insolubility and permanence of the silicious clothing of straw, point it out to the husbandman as the best natural material for covering hay-stacks and corn-ricks in the form of thatch.

Long unbroken straw is selected for this purpose, as it is water-proof, and allows the rain to trickle freely from its surface; but broken straw will not answer, because its silicious clothing is full of fissures or capillary channels, which would receive and retain a considerable portion of the rains of Autumn, or the snow waters of early Spring, and soon become rotten and useless as a protection against further inclemency of weather.

A thick layer of good thatch is a covering not only water-proof, but of exceedingly imperfect conducting

power, equally preventing the sudden penetration of heat and cold; thus in Summer, ice may be prevented from thawing by covering it thickly with straw; and in Winter, fruits may be preserved from frost by similar means.

The "bungalows" of India are built with baked or unbaked bricks, and they are generally thickly thatched, to prevent the transmission of heat; so are tents likewise protected from sun and rain by a straw thatch laid on frames of bamboo.

The limit prescribed for this general investigation concerning the phenomena of the Four Seasons, which admit of elucidation through the science of Chemistry, now demands the conclusion of this Chapter, relating to a few only of those which are presented during the beautiful season of Summer, and throughout it, whilst humbly considering, and endeavoring to explain the manifold and "wondrous works" by which we are surrounded, we have been inevitably led to extol the power and goodness of "The Great Workmaster."

"He that created the heavens and stretched them out; He that spread forth the earth, and that which cometh out of it; He that giveth breath unto the people upon it, and spirit to them that walk therein."

Numberless phenomena remain veiled in impenetrable mystery to all men, and regarding such, the lowly-minded and true "lovers of wisdom" make a full confession of their ignorance; but, unhappily, examples are numerous, of men proudly assuming the title of "philosophers," and so greatly estimating their own abilities, as to be ready, not only to explain everything, but dogmatically to state what MUST be the physical cause of everything, in the vast and perfect laboratory of Nature,

as if they were explaining the machinery, and demonstrating the motive power, of a work made with hands.

These are not "philosophers;" nor have they the remotest claim to the title, as they are deficient in its leading attribute, humility, for "Hardly do we guess aright at things that are upon earth; and with labor do we find the things that are before us."

CHAPTER III.

AUTUMN.

"He changeth the times and the seasons." He now ordains the reign of Autumn to commence, accompanied by the glorious sun, still shedding brilliancy and heat, for the advancement of the productions of the earth to the mature and bounteous harvest, the hope of which has so long cheered the husbandman throughout his anxious toils.

Many extraordinary and beneficial natural phenomena, several of which may be elucidated through the science of chemistry, are frequently presented in an equal degree during the end of Summer and the beginning of Autumn; these will accordingly now demand our attention; and in the first place, let us direct it in continuance of the investigation concerning the miraculous provision that is made to prevent the earth from the accumulation of a withering and destructive intensity of heat.

We have already found that the earth is capable of absorbing heat, though incapable of conducting it to any considerable extent; we shall now discover that the earth has likewise the power of parting with an excess of heat by radiation towards the unclouded Summer and Autumnal skies.

The meaning of the term "radiation" may be thus explained: suppose the circle in the centre of the annexed

engraving to represent a heated body; the star-like lines emanating from it may denote that heat is escaping, or radiating from it in all directions, quite independent of conduction or of convection.

Fig. 32.

A few simple experiments of the chemical laboratory will serve as an introduction to the grand natural phenomenon of radiation.

A plate of metal, either dull or bright, is an excellent conductor of heat; if, for example, a lighted coal be placed upon any part of its surface, this will soon become equally warm throughout its whole extent.

At the distance of four or five feet in front of a clear glowing fire, hold a large bright tin-plate, in any position, and it will not become warm; turn it about, present its surface at different angles to the fire, and at last a certain angle will be found, at which, although the plate remain cold, heat will instantly dart from its surface, and may be sensibly felt upon the face or hands.

Thus, in chemical language, heat is said to radiate from the glowing fire, through the intervening non-conducting air, to impinge upon the metal plate, and although it is an excellent conductor of mere heat of contact, as that of the lighted coal in the first experiment, it is not a conductor of this radiant heat which reaches it from

the distant fire; it is not even a retainer of this radiant heat; but it is an admirable reflector of this imponderable element, and accordingly it instantly darts upon surrounding objects, whilst the metal plate or reflecting surface remains perfectly cold.

Place the bright tin-plate flat upon a table, fold half a sheet of fine emery-paper smoothly round a small book, or a flat piece of cork, and with this rub the surface of the tin-plate all over, in the direction of its length; then do the same in that of its breadth; and thus effectually destroy all brightness or polish.

Now hold the tin-plate in front of the fire, as at first; it will soon become hot, and it will reflect but little heat; thus, by mere mechanical alteration of its surface, the metal is instantly rendered a retainer of radiant heat, and deprived of its power of reflecting such agent.

Select another tin-plate, brush one of its bright surfaces over with weak glue; then sift fine sand over this, and allow it to dry; thus the bright polish is covered, and not destroyed; and upon holding this sanded side in front of the fire, as already directed, the tin-plate will become hot, but no heat will be reflected.

Similar will be the result, if the tin-plate be painted with a mixture of weak glue and lamp-black, whiting, yellow ochre, Venetian red, Brunswick green, or any pigment that may be chosen.

In like manner, if a large flat surface of paving stone, or an unglazed earthen paving-tile, be held in front of the fire, no heat will be reflected from them; but they will absorb heat, and soon become warm.

The following striking experiments will afford farther illustrations concerning the extraordinary manner in

which the mere alteration of the lustre of a metallic surface affects its habitudes with radiant heat.

Select a large tin-plate, equally bright and polished on both sides, and with a strong pair of scissors, or small shears, cut it across to form two pieces similar in size; leave one of these without any further preparation, but blacken one side of the other with lamp-black, mixed with thin glue, and allow it to dry.

Provide a strip of wood, one foot long, one inch thick, and four inches wide, and with a saw, make two cuts or grooves across this, each of these being an inch from each of the ends of the wood, and each sufficiently deep to hold a tin-plate firm and upright when inserted on its shortest edge.

Place each plate in its groove, the black surface of the one being opposed to the bright surface of the other; attach a marble to the centre of the exterior surface of each with a lump of pomatum, then hold a red-hot heater of an "Italian iron" exactly between the plates, as shown in the annexed engraving.

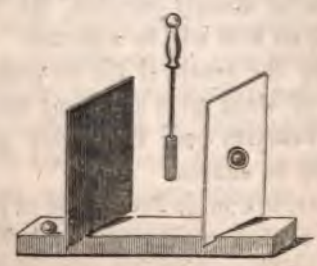

Fig. 33.

The plates are thus exposed to the same degree of heat that is radiating from the red-hot iron; but they have different habitudes with it; the bright surface will reflect

nearly all, and will not become sufficiently hot to melt the pomatum, and so cause the marble to drop; whilst the black surface will absorb nearly all, and will soon become sufficiently hot for such purpose.

By experimenting with great accuracy, the chemist has discovered, that as the unmetallic surface will absorb heat with the most facility, so will it part with such heat, or cool, or radiate such heat with the most facility; the following experiment will prove this fact sufficiently well for our present purpose.

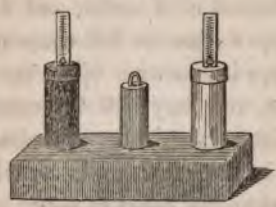

Fig. 34.

Take the tin canisters that were used in the experiment at page 113, cleanse the adhering oil from the one by washing it thoroughly with a strong solution of pearl-ash, then rinse it with water, and polish its exterior as bright as possible; paint the exterior of the other with the black mixture already described, and allow it to dry.

Pour an equal quantity of cold water into each, place on their respective covers, and insert the thermometers, that the bulbs may dip beneath the water, the bulb of the oily thermometer having been cleansed as above directed.

Lay a soft brick flat upon the table, and in its centre, with a knife or chisel make a hole about three-quarters of an inch deep, and sufficiently large to admit the end of the iron-heater of a tea-urn; make the heater red-hot,

and then drop it into the hole, and place a canister to stand at each end of the brick.

They will be equally distant from the radiant heat of the iron—indeed, more accurately so than the tin plates were in the last experiment—but still the black surface will heat the water the fastest, as an inspection of the thermometers will prove.

Let it heat to 100 degrees;—using a fresh heater, if necessary;—then remove the canister from the brick, and place it upon the table; remove the bright canister also, throw away its almost cold water, and fill it with water heated to the same degree as that contained in the black canister, and place it likewise upon the table;—watch the thermometers, and they will indicate that the water in the black canister is cooling, or radiating heat, more rapidly than that in the bright canister, which will remain sensibly warm when the other is cold.

These results are directly contrary to those which might be anticipated to ensue; we might think that by coating a metal plate with black paint, a bad conductor, it would prevent the heat from coming into contact with the metal beneath, and so keep it cold; and, on the other hand, the bad conductor would keep in the heat of the water; but the chemist proves that unmetallic, or earthy substances, though extremely bad conductors, are most excellent absorbers and radiators of heat.

Another curious and instructive experiment concerning this power of surfaces in radiating heat may be made by covering one of the sides of a cubical tin-plate canister with lamp-black, another with thin jelly, a third with writing-paper, and leaving the fourth bright and polished: then, upon filling the canister with boiling water, and approaching the sides in succession with the hands, or a

thermometer with a blackened bulb, the different radiating powers of the various coatings will be immediately detected.

The greatest heat will be found radiating from the lamp-black, the least from the polished surface, and if, for the sake of illustration, the heat from the lamp-black be supposed equal to one hundred, that from the writing paper is ninety-eight, from the jelly eighty, and from the polished surface only twelve.

"During all these experiments, it will be remarked how singularly these effects of radiation are opposed to the conducting powers of the respective surfaces; if we touch the clean part of the canister, it burns us; but we may place the finger with impunity upon the lamp-black, the paper, or the jelly, which, though good radiators, are bad conductors of heat."

Radiation not only proceeds from the immediate particles which form the surface of a body, but likewise from those at some distance beneath, and this curious fact may be easily determined; for example, take a cylindrical tin canister, and cover one half of its surface with a coating of extremely thin jelly, and the other half with four or five coatings of the same, letting one coat dry before another is applied; when all are dry, fill the canister with boiling water.

In this arrangement, although the nature of the two surfaces is precisely the same as regards material and smoothness, they will radiate very differently; the hand held at some little distance from the thin coating will not feel so hot as when held at the same distance from the thick coating, and if a thermometer, with a blackened bulb, be similarly held, it will indicate a small

elevation of temperature in the one case, but great in the other.

"In this experiment the increase of radiating power must be attributed to the increased quantity of radiating material, and it is discovered to continue until the coating amounts to the thickness of about one-hundredth part of any inch; after which no further increase takes place; it is inferred, therefore, that the particles constituting the jelly have the power of radiating, from a thickness below the actual surface, equal to the above amount."

As regards terrestrial radiant heat, meaning by the term that of a fire, or any other artificial source, the chemist discovers that surfaces, if similar in mechanical texture, may differ in color, without having their receptive or radiating power either increased or diminished; whilst, on the other hand, with solar radiant heat, he discovers that the colors of such surfaces do certainly affect both these powers most strangely; for dark-colored, or black, surfaces absorb and radiate more rapidly than such as are light-colored, or white.

Paint the bulb of one thermometer with the black mixture already mentioned, and the bulb of another, similar in size and graduation, with a mixture of whitening and glue, of equal thickness with the black; let these bulbs dry, and then expose the thermometers simultaneously to bright sunshine it will be immediately found that the black bulb absorbs heat quicker than the white bulb, by the greater rise of the mercury in its tube; and upon removing the two thermometers into the shade, probably the black bulb will indicate that it radiates heat quicker than the white bulb, by the more rapid descent of the mercury in its tube.

Again, nine pieces of equally fine kerseymere cloth, seven of them having the prismatic colors, and of the others, one black, and the other white, upon exposure to sunshine for the same time, will heat very differently, and of the colors, probably in the following order, the first being the hottest; violet, indigo, blue, green, red, orange and yellow; but the black cloth will surpass even the violet in temperature, whilst the white cloth will not even attain that of the yellow, as the application of the bulb of a thermometer will immediately prove.

From an experiment of this kind, we discover that "the warmth or coolness of clothing depends as well on its color as its quality; a white dress, or one of a light color, will always be cooler than one of the same quality, black, or of a dark color, and especially so in clear weather, where there is much sunshine; white, or presence of color, and very light hues, reflect heat copiously; but black, or absence of color, and very dark hues, reflect little."

"Experience has long supplied the place of science in directing the choice of clothing; the use of light colors always prevails in summer, and that of dark colors in winter."

Reasoning upon this property of black and dark surfaces in absorbing heat, a natural conclusion is drawn that the black skin or "rete mucosum" of the Ethiopian, would cause him to undergo severe suffering under the intensity of the tropical solar rays; but our experiments, be it remembered, have been made either upon inorganic matters, or matters deprived of vitality, and they do not hold good with bodies under the influence of the recon-

dite agencies of life, an extraordinary fact or anomaly, so called by the finite wisdom of man, is then presented.

The Creator, in His power and goodness, has mercifully ordained, that the skin of the Ethiopian shall absorb heat powerfully, but, at the same time, that it shall not sustain the slightest injury.

This extraordinary fact was originally investigated by a physiologist, in a series of extremely simple yet decisive experiments, of which the following are selected:

During an intensely hot day, he exposed the back of each hand to the sunshine for ten minutes, one hand being bare, and having a thermometer attached to it, the other being covered with black cloth, and having the bulb of a thermometer beneath this.

At the expiration of the above time, the exposed thermometer indicated eighty-five degrees, whilst the covered thermometer indicated ninety-one degrees; in a second trial, the former indicated ninety-one degrees, the latter ninety-four degrees; and in a third trial, the first thermometer indicated ninety-eight degrees, whilst the second indicated one hundred and six degrees.

In these three trials, the bare skin was powerfully scorched and raised in blisters, but the covered skin, though so much hotter, was not in the slightest degree injured.

Upon covering one hand with white cloth, and the other with black cloth, and exposing them for a similar time to sunshine, the former was invariably scorched, but the latter never affected.

The power of the solar rays to scorch the skin of man and animals is destroyed when these surfaces are black, although the absolute heat in consequence of the absorption of the rays is greater.

"The same wise Providence which has given so extraordinary a provision to the Negro for the defence of his skin, while living within the tropics, has extended it to the bottom of the eye, which otherwise would suffer in a greater or less degree when exposed to strong light; the retina from its transparency allowing it to pass through without injury."

The black or dark matter of the "retina" is technically called the "nigrum pigmentum," and is probably not absolutely necessary for vision, but only provided as a defence against strong light, since it is found to be much darker in the Ethiopian than in the European, and is of a lighter color in fair people than in dark, and therefore lightest in those countries farthest removed from the effects of the sun.

The scorching power of the solar rays being destroyed when received by black surfaces is an incontrovertible fact, and the only explanation that the chemist can offer regarding it is, that the mixture of heat and light in the solar rays is absorbed by black surfaces, and converted into sensible heat.

The sudden and fatal infliction called "the sunstroke" that frequently seizes reapers and laborers, in the intense heat of harvest time, is referred to the scorching effect of the solar rays, upon the scalp of the head, producing inflammation of the brain, and probably the first record of this is in the following Scripture passage.

"And when the child was grown, it fell on a day that he went out to his father to the reapers. And he said unto his father, My head, my head! And he said to a lad, Carry him to his mother. And when he had taken him, and brought him to his mother, he sat on her knees till noon, and then died."

In extremely hot climates the traveler is often "sun-stricken," and dies; and in allusion to the watchful care of Providence over His chosen people, it is said, "They shall not hunger nor thirst; neither shall the heat, nor sun smite them: for He that hath mercy on them, shall lead them; even by the springs of water shall he guide them."

The difference between the heating of dark and light-colored soils, when equally exposed to solar heat, and their difference in cooling when equally placed in the shade, as mentioned at page 107, may be now stated in technical terms, viz., that dark soils absorb heat more powerfully, and radiate heat more energetically than light-colored soils, which reflect a great portion of heat; we have now to examine how these facts, and others concerning the mere alteration of surfaces in affecting both absorption and radiation of heat, are applicable to the explanation of a beautiful phenomenon of Summer and Autumn.

The night has been serene, the moon and stars have shed their brilliant light, no clouds have obscured the heavens, no rain has fallen, and yet when we step forth at daybreak, we find the grass and the flowers of the field loaded with myriads of drops of water, sparkling like gems in the golden rays of the rising sun.

We recognize this beautiful phenomenon as Dew;—but from whence has it silently journeyed and arrived during the hours of night?—can the chemist reply?

He can; and the reply will furnish another example of the power and goodness of God, for "His favour is as dew upon the grass;" another proof of the ever-watchful care of Him with whom "the darkness and the light are both alike," whose hand is equally extended for the

protection of the animated creation during its noontide activity and its midnight repose.

Throughout the fervent glow of a Summer or Autumnal day, the solid opaque earth absorbs heat; this abides upon its mere surface, and is not conducted beneath; but at sunset, if the sky be cloudless and calm, the earth immediately radiates part of the heat upward, and soon becomes many degrees colder than the air directly incumbent upon its surface; accordingly the watery vapor that is present in the yet warm air, is chilled or condensed into drops of water, and these "distil as the dew" upon the earth, for the refreshment of its productions.

This phenomenon cannot fail of appearing remarkable, even to the most careless observer, and it becomes yet more so, when accurately investigated by the chemist. Examine a garden immediately after sunrise at this season; probably the grass-plat is saturated with dew; the gravel walk is nearly dry; the leaves of the hollyhock are dripping with water; the leaves of the laurel are free from moisture; but all these objects were similarly exposed to the night air, and if dew were a fine rain, as some persons imagine it to be, all should be equally covered with its drops; why is this difference observed?

Because the surfaces of the various objects differ in their radiating power; the grass-plat, and the leaves of the hollyhock are excellent radiators; they throw off heat with great energy, and so becoming cold, they induce a more copious deposition of water from the air than the gravel-walk and the laurel leaves, which, being bad radiators, retain heat, and remain so warm that the watery vapor in the air wafts over their surfaces without being chilled or condensed, and therefore they are free from dew.

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[redacted]

vapor condenses upon them and their productions as dew in abundance.

It is indeed a subject well calculated to arrest our attention, and excite our admiration and gratitude, when we thus find every soil, plant, shrub, and tree, has, by its own physical peculiarity of structure, induced the deposition of dew in proportion to its wants; and when we reflect that not a single dew-drop is created in vain, but each is measured by the Hand of Infinite Wisdom, and appointed to fulfill some useful end.

Some tracts of land, when clothed with vegetation, radiate heat with such vast energy that their low temperature not only causes the plentiful deposition of dew, but subsequently changes it into frost; but this extreme of cold, if continued, would be equally fatal to vegetable life as an extreme of heat; and as upon a former occasion, we discovered the Hand of Providence extending clouds for protecting the earth from the heat of noon, so upon this, do we discover the same Hand, extending them for preventing the undue escape of heat from the earth during the cold of night; "for His mercy is great above the heavens, and his truth reacheth unto the clouds."

These recondite accumulations of vapor, or clouds, intervening between the earth and the confines of the air, act as screens in arresting radiation from the earth to the sky, and also being warmer than the earth, they now radiate part of their own heat to it, and thus restore a due temperature to its chilled productions.

Moderate tranquillity of the air, and a serene sky, are essential requisites for the perfect deposition of dew, for very little takes place during the prevalence of winds, and none during that of clouds, unless they are exceed-

highly high in the air, because the former disturb, and the latter arrest, the radiation of heat from the earth.

During a fine Summer or Autumnal night, the following curious and instructive experiments can be made regarding this beautiful phenomenon of dew.

Weigh some dry wool into two portions of twenty grains each, for example; then bend a large sheet of pasteboard in half, to form a kind of pent-house; place this with its ridge uppermost on a closely mown grass-plat, and lay one of the portions of wool on the middle of the grass beneath the pent-house; and the other portion on the adjacent grass fully exposed to the sky.

Fig. 35.

Examine this arrangement at sunrise, and the sheltered wool will be found to have increased only about four grains in weight, whilst the exposed portion will probably have increased about thirty-two grains; the slight pent-house, although open at both ends, and admitting the free access of air, yet preventing, in a remarkable degree, the direct radiation of heat from the wool, and accordingly opposing any great deposition of dew; in fact throughout the night it has been warmer beneath the pent-house than in the open air.

The foregoing experiment admits of variation to prove that even more partial shelter from direct radiation causes the deposition of dew in smaller quantity than that which falls upon objects fully exposed, and it will entirely

re the notion that dew is a kind of fine rain, falling
he atmosphere.

ce a few bricks upon a grass-plat, to form a small
about three feet in height; at the foot of this spread
y grains of dry wool, and some feet distant place a
r weight of the same substance; let this arrange-
remain during the night, and upon examining it at
e next morning, (always providing no rain have
,) the partially sheltered wool will be found to have
ısed only a few grains in weight, whilst the exposed
n eight or ten times as many grains in weight.

Fig. 36.

ıvel walks, and stone pavements, radiate heat and
re dew, less readily than grass-plats, hence, wool
l on the former has its temperature less depressed
ɔn the latter, and therefore obtains less dew; and
ffect is by no means referable to the capillary attrac-
f the fibres of the wool, for it ensues equally well
wool be placed in a clean saucer; nor is it refera-
hygrometric attraction of water from the air, be-
wool, placed upon a board, elevated at some feet
the earth, during a cloudy night, will acquire only
y minute increase of weight; the effect is entirely
ıdent upon radiating power.

fore the cause of dew was discovered, scientific

inquirers were at a loss to account for the principle upon which a thin mat, employed by gardeners, protected tender plants from cold; it appeared scarcely possible, that such a slight covering could have any effect in preventing them from attaining the temperature of the external air, and yet common experience proved its utility.

When the discovery was made, that bodies on the surface of the earth become much colder than the atmosphere, by radiating heat during a still and serene night, the true reason of the gardener's homely practice of covering plants with matting, was fully evident; it prevented radiation from taking place.

Fig. 37.

In order to acquire precise information upon this subject, the following simple arrangement was made: the experimenter "fixed perpendicularly in the earth of a grass-plat, four small sticks, and over their upper extremities, which were six inches above the grass, and formed the corners of a square, whose sides were two feet long, a very thin cambric handkerchief was tightly drawn.

"Therefore nothing existed to prevent the free passage of air from the exposed grass, to that which was sheltered, except the four small sticks, and there was no substance to radiate downwards to the latter grass, except the cambric handkerchief."

"The sheltered grass, however, was found nearly of the same temperature as the air, while the unsheltered was 5 degrees or more colder; one night the fully exposed grass was 11 degrees colder than the air, but the sheltered grass was only 3 degrees colder."

Hence we see the power of an awning, infinitely more slight in texture than that of matting, in averting or lessening the coldness of the ground that would otherwise occur, and be injurious to plants.

It is for this reason that a tent, or marquee, although merely constructed of thin canvas, and by no means air-tight, becomes a comparatively warm shelter during a cold night; no dew will be found upon the plat of grass shielded by the tent, but abundance upon that exposed to the open air around.

A piece of matting, that has covered a plant during an autumnal night, will be found copiously bedewed, whilst the plant remains dry; the matting having presented its radiating surface, and parted with heat, which otherwise the plant would have done; nay, even the matting occasionally performs this office with such energy, that its surface becomes covered with hoar-frost, from which it suffers no injury, as it has no vitality, whilst it shields the living plant, that otherwise would be compelled to radiate, and perish, by the degree of cold induced by its own power.

In some countries, the temperature never falls to the freezing point of water, and yet ice may be procured by taking advantage of the radiation of heat from surfaces, in the following manner.

A layer of dry straw, or stubble, is spread in an open situation during a calm and cloudless night, and upon this surface are placed shallow earthen pans, filled with

water; radiation immediately commences from the straw and the water; both lose heat so rapidly and so effectually, that the water can no longer remain liquid, and therefore becomes covered with a thin crust of ice.

It has been already stated, that water hastens the putrefaction of dead vegetable substances; the same remark is applicable to those of animal origin; in warm climates, more especially, the deposition of water, in the form of dew upon these, induces putrefaction with great rapidity; and as this generally happens only during clear bright nights, it was anciently supposed that moonlight favored animal corruption.

The moon, when at full, reflects upon the earth only about one three-hundred-thousandth part of the light of the sun; and the lunar rays, even when concentrated by a powerful lens, and the focus directed upon the bulb of a delicate thermometer, do not affect it in the slightest degree; hence the phrase, "the pale, cold moon," is not only poetically beautiful, but philosophically correct; and as the light alone will not induce putrefaction, and as there is no heat, the phenomenon appears to be solely referable to the radiating power of animal substances inducing a copious deposition of dew upon their surfaces, for water is essentially requisite in all cases of putrefactive changes.

If a thermometer be placed upon a grass-plat, it will very frequently indicate a temperature of fifteen or twenty degrees colder than one suspended over the grass, at the height of three or four feet, thus proving that radiation is proceeding with extreme rapidity in the one case, from the comparatively solid vegetable matter and the soil, but not from the ambient air.

Accordingly, the portions of air in immediate contact

with the grass, become much colder than those far above, and are compelled to deposit dew; and if the air over a given locality remain tranquil for some hours, this phenomenon will solely ensue from the lower and colder portions.

Small valleys, and hollow-ways, permit the air to repose undisturbed; and although they are apparently situations sheltered from cold, yet they are frequently more subject to reduction of temperature than higher situations; and accordingly, much to our surprise, we find delicate plants chilled, or even frost-bitten, in hollows, whilst others suffer no injury upon the adjacent slopes.

"In the close and sheltered streets of cities, the deposition of dew is very rarely observed, because there the objects are necessarily exposed to each other's radiation, and an interchange of heat takes place, which maintains them at a temperature uniform with that of the air; a deposition of dew in this case can only take place when the natural temperature of the air falls below its point of saturation."

At sunrise during Summer or Autumn, we may frequently see a dense white mist, only a few feet in height, directly incumbent upon a grass or corn-field, whilst the air above is clear and bright with the rays of the sun; and we may even walk along the foot-path across the field, with the lower part of our body enveloped in this mist, whilst the upper is perfectly free from its humidity.

This phenomenon of mist is consequent upon the calm of the previous night having admitted rapid radiation to ensue from the earth, which then became so much colder than the great volume of the atmosphere above, that the portion in immediate contact with the earth was suddenly

deprived of a large amount of its aqueous vapor, and then the mist, or "earth-cloud," thus formed, prevented any farther radiation from ensuing towards the clear sky, and therefore remained until dawn.

Let us now remark another beautiful phenomenon in connection with our present subject of inquiry:—although at sunrise the dense mist reposes upon the surface of such tracts of land, and although innumerable dew-drops bespangle the trees, plants, herbs, and flowers of others, yet as the sun mounts higher in the heavens to run its appointed course, both mist and dew vanish and the earth and its productions become dry; how is this?

Because the water of the mist and dew gains sufficient heat, to change from the state of visible liquid to that of invisible vapor; this the air immediately receives, and treasures in its capacious volume, throughout the glowing day; and then at its close, if the sky be calm and cloudless, the earth and its productions again radiate the stores of heat which they had withdrawn from the noontide intensity; they again become cooled, and the air commences its wonderful work of relinquishing its aqueous store as mist and dew, in just proportion for the relief of all.

Thus, in the sublime and all-powerful language of Scripture, "Dew after heat refresheth:—to everything there is a season:—and shall not the dew assuage the heat?"

Or, in the imperfect and limited terms of science, thus the earth, by its peculiar habitudes as regards the reception and retention of solar heat, resists an excessive or destructive accumulation of this powerful, imponderable

agent, and maintains a temperature conducive to the well-being of the animated creation.

These are the pleasures and advantages of the proper pursuit of science, to examine, and if possible, interpret the varied phenomena around us, which preserve the order and harmony of the Creation; they all unfold volumes of wonders, and prove, as in the case that we have been considering, "who seeketh Wisdom early, shall have no great travail, for he shall find her sitting at his doors."

It is only of late years that man has been permitted to interpret and understand the cause of dew, but from the earliest ages he has experienced and acknowledged its wonderful and beneficial effects, and more particularly in those countries where rain seldom or ever falls; hence the Sacred Writings so abound in eloquent passages, and splendid metaphors, concerning the blessings which emanated from the presence of dew, and the miseries entailed by its absence, of which the following have been selected:

"For the seed shall be prosperous; the vine shall give her fruit, and the ground shall give her increase, and the heavens shall give their dew."

"God give thee of the dew of heaven, the fatness of the earth, and plenty of corn and wine."

"The heaven over you is stayed from dew, and the earth is stayed from her fruit."

"I will make your heaven as iron, and your earth as brass."

The metaphor of the last passage is thus humbly interpreted: that the intense power of the sun should directly heat the air, and render it so arid, that neither dew nor rain should descend, and that the earth should

consequently be so parched and hardened, as to be rendered incapable of being ploughed into furrows for the reception of seed.

Knowledge concerning the phenomena and laws of the Creation, is not revealed to man, and he must attain it by the proper use of his noblest faculties; and the subjects which he now classes into the form of a science, when mentioned in Scripture, are always couched in language accommodated to sensible appearances, and popular notions, as in the foregoing, and many other passages that have been, and yet remain to be adduced.

In Egypt, the wind that traverses extensive tracts of sandy deserts, is so dried as to deposit no dew; whilst that which crosses the Mediterranean, is so saturated as to deposit it in abundance.

In this country, the deposition of dew from the atmosphere is generally less during the continuance of easterly, than of westerly winds, a phenomenon attributable to the different nature of the surfaces over which these winds travel, the former crossing the continent of Europe, and thus becoming comparatively dry or arid, the latter sweeping across the vast expanse of the Atlantic ocean, and therefore becoming moist or hydrated, requiring but little reduction of their temperature for the copious deposition of dew to ensue upon terrestrial objects.

The mere form of a drop of rain or of dew, presents matter of inquiry to the philosophic mind; why is it either a perfect sphere, or some modification of a sphere, and not cubical, or octohedral, or other angular figure; and why does it equally adhere to the upper and under surfaces of the blades of grass?

Because the impress of perfection is set upon every work of the Creator, and He permits man to discover

that a sphere is a perfect and simple figure, the constituent particles of which are equally distant from one common centre of attraction, and thus being equally and simultaneously attracted, no other figure can possibly result, unless some superior external attractive force be presented.

Fig. 38.

A sphere is the figure assumed by liquid water, when a portion of it is either perfectly unsupported, or supported upon a surface having little attraction for it; but it becomes more or less spheroidal, or ultimately disappears, in proportion to the extraneous attraction of the surfaces upon which it is received.

Thus a drop of rain or of dew, in descending from the air, is a sphere, and will so continue when received only at a minute point of contact by the upper surface of a dry blade of grass, and even gently roll unto its extremity, and pass to the under surface, and there remain pendent in opposition to the attraction of gravitation which is soliciting its return to the earth, the attractive force of the minute point of contact with the blade of grass, being superior for a time to that of gravitation.

If several drops coalesce into one large drop, the point of solid contact likewise increases, and then becomes far superior to the attractive force between the mobile liquid particles, and thus drawing them away from each other, produces a spheroid; but this will remain well

defined upon the upper surface of the blade of grass, even continue pendent from the lower.

By successive additions, its size becomes so great, that the surfaces can no longer oppose the attraction of gravitation, and therefore the spheroidal drop becomes more and more oblate, until it rolls or falls away, and immediately loses its form amidst the capillary channels of the earth, from whence it is destined to ascend as vapor, to mingle with the air, and again to descend as rain or dew, or other forms suited alike to time and season, for not even a drop of water is lost or annihilated in the laboratory of Nature.

When drops of water fall heavily upon the generality of vegetable productions, the abrupt shock forces them into such extensive contact with these surfaces, and also with each other, that in place of remaining as beautifully defined spheres and spheroids, they rapidly coalesce as a slender stream of water, and thus flow away into the soil, with the exception of a comparatively few drops, which sometimes escaping this sudden attraction, remain yet clinging to that of the terminal points of the leaves.

The surfaces of many leaves are covered with an extremely fine powder, which,—like fine dust upon the floor of an apartment,—is repulsive of gently sprinkled water; thus, upon the leaves of the cabbage and the garden poppy, brilliant globules repose, and if shaken by the wind, or by the hand, they rapidly glide about without wetting the surface; and although they may divide into many more globules, the most minute always having the most perfect spherical form, they immediately exert attraction for each other when allowed to come into mutual contact, and coalesce into one or two large spheroidal forms of silvery radiance.

for a considerable time beneath the water, and then rise buoyantly to its rippling surface with unwetted and unruffled plumage.

Even the loose feathers that escape when birds are pluming on the banks of the water, are wafted by the wind upon its surface, and as they gently sail along, they afford matter of reflection to a philosophic mind; for the slightest occurrence in Nature surely cannot be unworthy the attention of man.

Again, during a summer or autumnal evening, it is both interesting and instructive to stand on the bank of a calm sheet of water, and watch the swarms of exquisitely-formed insects, with delicate and slender limbs so perfectly repellent of water, that are running, or rather darting, upon its actual surface, and scarcely depressing or disturbing its smooth and glassy tranquillity.

The foregoing, and many similar phenomena, must have been remarked by the most indifferent observer; they are popularly called instances of the "repulsions of water, by pulverulent or oily substances;" but the correct philosophical expression is, that such surfaces have not so great an attraction for the drops of water as their constituent particles have for each other, and therefore they preserve as much as possible the spherical form which they had when entirely deprived of support.

The dew that we have been considering, consists of water very nearly pure, and is therefore perfectly different to a thick sweet liquid that is frequently observed to collect on the leaves of trees during Autumn, and is popularly called "honey-dew."

This liquid is shed by a species of insect, known to the Entomologist under the name of the "Aphis;" it

dwells upon the under side of the leaves, and when this "honey-dew" escapes from its body, it is received upon the upper surface of the leaves below; this liquid is very deleterious to vegetation; it fills the pores of the leaves, and disturbs their proper functions of transpiration and absorption; they soon become diseased, and from being originally of a brilliant green, they turn to a dingy yellow color.

But this "honey-dew" is a favorite food with ants, and they may very frequently be observed crawling up exceedingly lofty trees, in order to gain a supply of it from the leaves.

Several contrivances for denoting the existence of watery vapor in the atmosphere, or, in other words, its relative dampness and dryness, have been already noticed at page 138, under the name of "Hygroscopes," the principle of an instrument for denoting, or actually measuring, the quantity of aqueous vapor in the atmosphere, now demands our attention, and it properly bears the name of a "Hygrometer;" its form is shown in the annexed engraving.

Fig. 40.

It consists of a small and delicately constructed "Cry-

ophorus," (page 133,) but containing the liquid called Ether, instead of Water; the two thin glass bulbs are about one inch and a quarter in diameter, and are connected by a glass tube, the horizontal part of which is about the eighth of an inch, and the perpendicular, about a quarter of an inch internal diameter; the horizontal part is only thus made of thicker glass, that it may be stronger, and not so liable to break when inserted into the small spring clip, on the top of the brass standard or column, to the shaft of which is attached a small and delicate mercurial thermometer.

The horizontal part of the tube is about four inches, and the perpendicular part, six inches in length; this latter includes another and equally delicate thermometer, but having an elongated, or pear-shaped bulb, merely to facilitate its introduction into a tube so small; and this bulb dips fairly into the ether, with which one of the glass bulbs already described is three-quarters filled.

The other bulb, attached to the upper and shorter part of the tube, is smoothly covered with a piece of fine cambric, secured around the tube by thread; a small capillary neck, closed by melting the glass, projects about a quarter of an inch beyond this covering. This is the appearance of the instrument, but its construction is as follows: the perpendicular tube, with its bulb, is first made, and the small thermometer introduced; then the horizontal tube and its bulb, with the capillary neck open, are made; the left hand extremity of this tube is then melted, or welded, to the perpendicular tube; after this is done, ether is introduced through the capillary neck, until the bulb unto which it belongs is nearly filled; and then, by inverting the instrument thus far

constructed, the ether is caused to flow into the bulb attached to the tube containing the thermometer.

The gentle heat of a lamp is then applied to this bulb, that the ether may boil; this it will do at 96 degrees; its vapor perfectly expels all the air from the interior of the instrument through the capillary neck; and when the vapor itself fully and fairly issues forth, the opening of the neck is suddenly closed by melting it in the flame of a lamp.

Thus the greater portion of the ether still remains in a vacuum, as far as the absence of air is concerned, and only subject to the pressure of its own vapor, as was the water in the "Cryophorus;" the bulb is then developed in cambric, and the instrument is completed.

Now as regards the method of using it, or of causing it to act as a Hygrometer:—should any ether enter the covered bulb, this must be grasped in the hand, and by holding it as directed for the "Cryophorus," the heat of the hand will expand the vapor, and force the liquid ether into the other bulb; at the same time a sensation of cold will be felt, because ether, although more volatile than water, still requires heat for its evaporation; and this it takes from the hand, which, losing heat, feels cold.

When all the ether has entered its proper bulb, the instrument is placed upon the standard, and then set at an open window,—or, still better, in the free atmosphere —on some steady support, level with the eye, taking care, if possible, that a dark tree or wall, or a black hat, at some few feet distant, will throw it out into strong relief.

An examination of the thermometer attached to the

brass standard, and of that enclosed in the glass tube, with its pear-shaped bulb dipping into the ether, will prove that they both indicate the same temperature: this must be noted; and then from a small bottle, provided with a conical tube stopper, as shown in the next engraving, a few drops of ether are let fall upon the cambric envelop.

Fig. 41.

Ether being exceedingly volatile,—infinitely more so than water,—will immediately gain heat from the bulb, for its conversion into vapor, or its evaporation; the bulb will be reduced in temperature, and the vapor of ether that it contains will be condensed therein into liquid ether, as was the vapor of the water, first condensed into liquid water in the experiment with the "Cryophorus."

As in that case, a call or demand is now immediately made upon the bulb containing the thermometer and the liquid ether, for a portion of vapor to supply the place of that which has been condensed; and there being no air in the instrument to oppose this demand, it is instantly supplied by gaining heat from the bulb in which the ether is contained.

This vapor in its turn is instantly condensed; but as the ether evaporates from the capillary attraction of the cambric, another, and another, and many calls, are so quickly made, that the bulb containing the ether, by

yielding heat, becomes extremely cold,—as its included thermometer will indicate,—and at length becomes so cold, that the watery vapor contained in the atmosphere coming into contact with it, is condensed, as a fine ring of dew upon its surface at the level of the remaining ether.

This is instantly detected, by the strong relief into which the transparent bulb is thrown by the dark object, and the included thermometer shows the degree of temperature at which this phenomenon ensues; it must be immediately noted, and it is technically called "The dew-point."

Suppose the external thermometer indicate 60 degrees, and the internal thermometer indicate 48 degrees, the difference between the two is 12 degrees, and therefore the atmosphere does not contain a very large amount of watery vapor, since a reduction of temperature so considerable, is required for the deposition of dew; but suppose the one thermometer indicate 66 degrees, and the other 64 degrees, the difference between the two is only 2 degrees, and therefore the atmosphere does contain a very considerable amount of watery vapor, since it is immediately prone to deposit dew by such a slight reduction of temperature; therefore, in the first example, the degree of its dryness may be denoted by 12, and in the second by 2 degrees.

Or, the fact may be stated in the following terms, namely: the more widely that the thermometers differ in their indications, the smaller is the quantity of the vapor in the atmosphere; and the more closely that they agree, the greater is the quantity of the vapor contained in the atmosphere.

For example; in exceedingly dry weather, the cam-

brass standard, ...ated with ether more
with its pear-shap... ... sufficient cold to sum-
prove that they b... ...spheric vapor to chill and
must be noted; ... ...ther hand, in exceedingly
with a conical tub... ... a very few drops of ether
graving, a few ... ...y summon the large quantity
bric envelop... ...mosphere is almost saturated,
...—to condense and deposit as

...f these facts may be gained, by
hygrometer" in a hot dry room,
... will be observed between the
... moment of the "dew point;" and
...p cellar, when little difference will
... hem at the moment of the "dew
...he air of the cellar be already na-
...th vapor, or the air of a small apart-
... saturated with vapor, by a large wet
...ung within it, the two thermometers
...e at the moment of the deposition of
... the "dew point."

... degree of atmospheric dryness, or
...very vapor, as measured by the ther-
... "hygrometer," seldom amounts to 30
... say, the "dew point" is seldom 30
... the temperature of the air; but in the
...—an island which is situated near
... of the river Ganges,—at a temperature
... the "dew point" has been seen as low as
... marking the dryness or aridness of that
...mosphere at 61 degrees.

In ... scientific investigations, accurate experi-
... made with the "hygrometer," and

aborate tables have been constructed, to show the actual eight of aqueous vapor locally contained in the atmo- here, at the time that the "dew point" is ascertained: it these tables or calculations, although highly interest- g and important to professed meteorologists and chem- :s, would scarcely be intelligible to general readers and venile students; therefore no reference is made to them iring this slight inquiry regarding the phenomena of the our Seasons.

What has been stated concerning the construction and ethod of employing the "hygrometer," the manner in hich it may be caused to act as "a weather-glass,"— the popular acceptation of the term,—to indicate the yness and dampness of the atmosphere, and therefore e lesser or greater probability of rain, may be suffi- ently intelligible.

Watery vapor, although invariably present in the hole atmosphere, and its mean quantity expressed by e enormous sum at page 28, is liable to local variations its quantity, according to the local temperature of any irticular volume of the atmosphere; for instance, it is own at page 130, that warm air, either calm, or moving a breeze, or as a high wind, is capable of evaporating id sustaining in its invisible volume more water than old air, under similar conditions of repose and motion.

It has been ascertained, during most refined, accurate, id laborious experiments, conducted both by the me- orologist and the chemist, that a cubic foot of abso- itely dry or anhydrous air, *i. e.*, air consisting of Nitrogen, xygen, and Carbonic acid, when at the temperature of 3 degrees, or near the "freezing point" of water, does ot absorb or sustain more than two grains and one-third f a grain of watery vapor; whilst at the temperature of

60 degrees, by such increase of heat, it will sustain five grains and three quarters of a grain; and at the temperature of 70 degrees, by such further increase of heat, it will sustain eight grains.

This experimental fact immediately accounts for the greater rapidity with which a pool, or other accumulation of stagnant water, is "dried away"—even by the naturally hydrated atmosphere—in warm weather than in cold weather; and it also, in a great measure, accounts for the more copious deposition of dew from the atmosphere in the one season than in the other.

In some cases, a parched volume of the atmosphere in motion, as "wind" traveling from one clime to another, over the wide expanse of sea or ocean, incites the rise, and accumulates the burden of so large a proportion of pure watery vapor upon its "wings," as to be at length unable to sustain the whole; and then, during its flight or transit, a portion is slowly and gently relinquished in the mysterious form of clouds.

These eventually descend as rain upon the earth; but in other cases, a parched volume or blast of wind is ordained to sweep over arid sands or deserts, and in place of refreshing these with a copious supply of water, it actually deprives them of their very scanty store of this invaluable fluid for its own hydration, and thus often causes a most intense and almost insupportable sensation of heat.

These phenomena are most particularly evident in Eastern climates, and being familiar to the most ignorant observers, they were chosen by the Savior of mankind as a medium for conveying a just and powerful reproof to the captious malevolence of benighted minds, concerning the utter vanity of physical observation and

knowledge, if not combined with full perception, and confession of the transcendent excellency of Faith.

"When ye see a cloud rise out of the west, straightway ye say, there cometh a shower; and so it is."

"And when ye see the south wind blow, ye say, there will be heat; and it cometh to pass."

"Ye hypocrites, ye can discern the face of the sky and of the earth; but how is it that ye cannot discern this time?"

"Yea, and why even of yourselves judge ye not what is right?"

The physical explanation of the phenomena to which this powerful allusion is made, may be thus rendered;—the Mediterranean Sea is situated immediately to the west of Judea, and during the prevalence of a westerly wind, yields sufficient vapor to form a cloud of rain, for the refreshment of the land; whilst the hot countries of Egypt, Ethiopia, and Arabia, situated immediately to the south of Judea, during the prevalence of a southerly wind, so greatly deprive it of moisture as to parch the land on which it ultimately arrives.

To minds duly prepared, the observation and study of the "magnificent history of Wisdom and Intelligence, which is written in legible characters both in the heavens and on the earth," are an inexhaustible source of happiness; which can never prove incompatible with the exalting influence of the Scriptures, since both emanate from One Omnipotent Being, as faithful messengers, to direct the humble approach of man towards the Throne of His Mercy and of His Power.

The Scriptures do not contain a single prohibition regarding the acquisition of wisdom and understanding concerning the phenomena of the Universe; on the

contrary, they first set forth the rudiments of such philosophy in the circumstantial language of history; and subsequently enjoin its search in the sublimest strains of poetry, and extol the pleasures and advantages of its discovery in the attractive charms of proverb and of song.

First, as regards the rudiments and goodness of philosophical knowledge; secondly, as enjoining its search; and, thirdly, as extolling its discovery.

The Scriptures thus testify:

I. "In the beginning God created the heaven and the earth," *et seq.*

"And God saw everything that He had made, and behold it was very good."

II. "The works of the Lord are great, sought out of all them that have pleasure therein."

Worthy, that is, of being inquired into, and studied by all that delight in obedience to His will; and such only can appreciate His power.

III. "Happy is the man that findeth wisdom, and the man that getteth understanding."

The refined joy and happiness of the man that finds pure knowledge, are here—to suit human comprehension—likened to the ordinary elation and gladness of the man that either directly finds a pure vein of precious metal, or indirectly succeeds in getting or drawing it out in purity and value from an ore by his own application and labor; the terms "finding" and "getting," as in remote ages, are even now employed for denoting such discoveries.

The inestimable worth of pure knowledge is then placed in direct and powerful contrast with the insignificant value of metallic riches.

"For the merchandize of it is better than the merchandize of silver, and the gain thereof than fine gold."

Truly inestimable are the varied phenomena presented in the wide realm of Nature throughout the revolving year; and those we cannot comprehend, still awaken in our minds the most glowing feelings of gratitude and admiration.

Thus the physical cause of the blue color of the sky cannot be satisfactorily explained through the medium of science; and yet at all seasons, we acknowledge its surpassing beauty, more especially, perhaps, in Autumn.

The atmosphere immediately incumbent upon the earth, has probably the power of absorbing and retaining more of the blue rays of light than that at greater altitudes; and thus, when we cast our eyes on high, we look through a volume of the densest air, replete with blue light; and so likewise, if we look abroad over an extensive tract of country, the horizon of which is formed by distant hills, they appear blue, or, in other words, they partake of the color of the medium through which they are viewed; if we journey to them, their blue color gradually vanishes, and at length their ordinary colors appear; and now, looking from the hills towards the spot from whence we journeyed, it in turn appears blue.

"The ridge called 'The Blue Mountains,' in Australia, another of the same name in America, and many others elsewhere, are not really blue, for they possess all the diversity of scenery which their climates can give; but to the eye which first discovered them, bent on them generally from a distance, they all at first appeared blue, and they have retained the name."

The air contained in a spacious hall or room, is too small in volume to affect the eye with an impression of

blue color, and all objects appear of their natural tint; the same as an alabaster figure will appear beautifully white when viewed through a thin glass shade, but will gradually appear green, upon being covered with three or four additional shades, although they are of equal thickness and transparency; and if several more be employed, the vase will at length become invisible.

The red appearance of the evening and morning sky, so popularly known as indicative of fair and foul weather, was chosen by the Saviour of mankind, as the medium of a reproof, similar in its force and tendency to that which has already engaged our attention, in humbly endeavoring to present its philosophical interpretation.

"When it is evening ye say, it will be fair weather, for the sky is red."

"And in the morning, it will be foul weather to-day, for the sky is red and lowering."

The astronomer proves, that in consequence of the refractive or light-bending power of the atmosphere, the sun is visible for a considerable time after actual sunset, and also before actual sunrise; the chemist ascertains the fact, that at actual sunset, the surface of the earth radiates heat, and the watery vapor present throughout a vast height of the atmosphere, immediately enters into a state of incipient condensation; he therefore presumes the glow of light that so often blushes in the sky during a summer or autumnal sunset, may depend upon the vesicular vapor reflecting the red rays more powerfully than the others, for he discovers, that if light be transmitted through steam mingled with air,—and therefore on the verge of condensation,—that it assumes a deep orange or red color.

"The red color of the sky at sunset, is indicative of fine weather; for although watery vapor is present in the air, it is probably only on the verge of incipient condensation, and not sufficiently condensed to form rain-clouds; and this slowly progressive transition of vast volumes of the air through the temperature of the dew-point, can only occur in serene weather at sunset, and not at sunrise."

"The red and lowering appearance of the morning sky, which indicates foul weather, probably depends upon such an excess of vapor being present in the whole atmosphere, that clouds are actually forming in the higher regions, contrary to the direct tendency of the rising sun to dissipate them; they accordingly reflect the red rays of light abundantly, and are considered as announcing a speedy precipitation of rain."

"In the morning, in fine weather, the strata of the air near the surface of the earth alone, and in the lowest and most sheltered spots, are in a state of absolute dampness; the more elevated regions are comparatively free from humidity, and the morning light is gray; the vapors which, during the reversion of the process, might probably reflect the red rays, are not elevated until the action of the sun upon the surface of the earth has continued long enough to impart a sensible warmth, by which time the moment of sunrise is past, and the sun has risen above the horizontal vapors."

The close observance of natural phenomena by our ancestors, gave rise to many sayings and proverbs, of which several have been presented; and we find another concerning the appearance of the skies that we have just considered.

"An evening red, and morning gray,
Will set the traveler on his way;
But an evening gray, and a morning red,
Will pour down rain on the traveler's head."

The "rainbow," that so frequently adorns and glads the clouded watery heavens, in full display of gorgeous-colored zones of first-created light, as "the token of the covenant between God and man, that the waters shall no more become a flood to destroy all flesh," must be esteemed as the most beautiful and magnificent atmospheric phenomenon that we behold throughout the Four Seasons of the revolving year.

This phenomenon, however, does not admit of explanation through the medium of Chemistry; its interpretation belongs to the very highest departments of the science of Optics, and there probably we only know it in part; but even such part, if it could be here admitted, would more than occupy the remaining limits that are assigned for the actual chemical phenomena of Autumn and Winter.

But we are inevitably led for a few moments to quit the direct province of Chemistry, and trespass upon that of Optics, for unfolding the probable physical cause of the rainbow, in concise and intelligible terms.

The rainbow invariably appears in that part of the heavens which during the day is directly opposite to the sun, and whilst rain is falling between the dark clouds in the one quarter, and the solar beams in the other; these, under most circumstances, impinging upon pellucid drops of water, will either directly pass through them in right lines, or, if refracted from such course, they will, upon emerging from the drops, immediately resume it, and pass onward as colorless light.

Under certain natural conditions, which merely to facilitate our inquiry may for the moment be called extraordinary, the solar rays impinging upon drops of water, will not only pass through them, or be simply refracted, as above, but upon emerging from the drops, a portion of the rays will continue to pass onward as colorless light after ordinary refraction; whilst another portion deviates from such path, and is further refracted, or broken, into seven extraordinary-colored rays, or prismatic rays, as mentioned at page 36 of the Introductory Chapter.

This extraordinary or colored refraction or analysis of solar light, is frequently presented by drops of morning dew, but in greater perfection by drops of rain, in falling through the atmosphere, between a dark cloud and the brilliant sun, the rays of which, entering and emerging from successive drops, are refracted into Violet light, which departs farthest from the path that the unaltered rays would have pursued, and into Red light, which keeps nearest the path that the unaltered rays would have pursued; thus the external and the internal fringes of the rainbow are formed, and they include within their zones the remaining colored rays in the order of their inherent refrangibility, the Indigo, Blue, and Green, being nearest the Violet, whilst the Yellow and Orange are nearest the Red; thus presenting a perfect rainbow of the seven colors of analyzed light.

Or, in more technical terms, the Violet, Indigo, Blue, and Green rays, are the most refrangible, whilst the Yellow, Orange, and Red, are the least refrangible rays of solar light; the rainbow, therefore, is said to present a magnificent natural example of its analysis; for the colored rays cannot be divided into others.

When a single and perfect rainbow appears, its interior fringe is Red, and its exterior fringe is Violet; but a "double rainbow" is most frequent; a phenomenon, that is, of one bow within another; and then not only are the colors of the inner and smaller, or Primary bow, more vivid than those of the outer and larger, or Secondary bow, but they are exactly in the reverse order, the interior fringe of the inner bow being Violet, and its exterior fringe being Red.

Fig. 42.

The form of the "double rainbow" the artist has successfully represented in the above engraving, the dark shading of the bows denoting their respective fringes of violet light, as the employment of surfaces to reflect individual colors is impracticable in this department of art; indeed, when we consider that the effect of an engraving depends upon the total reflection of one portion of colorless light, by the surface of the paper, and the total absorption of another portion by the surface of the ink, it becomes extraordinary that simple engravings should convey to the eye any correct notion of the appearances of surrounding objects.

The following ancient and popular proverb concern-

ing the "rainbow," affords one more example of a refined physical truth appearing in plain homely guise:—

"A rainbow in the morning, is the shepherd's warning,
A rainbow at night, is the shepherd's delight."

"This old proverb is generally correct, as a rainbow can only occur when the clouds containing or depositing the rain are opposite to the sun; and in the evening the rainbow is in the East; and in the morning in the West; and as our heavy rains in this climate are usually brought by the westerly wind, a rainbow in the West indicates that the bad weather is on the road by the wind to us; whereas the rainbow in the East proves that the rain in the clouds is passing from us."

"As an indication of wet weather approaching, nothing is more certain than a halo round the moon, which is produced by the precipitated water, and the larger the circle, the nearer the clouds, and consequently the more ready to fall."

All things demand equal attention from him who truly loves and desires knowledge; thus the foregoing explanation of the homely proverb emanated from the most enlightened philosopher that ever devoted his talents to the fascinating science of Chemistry.

Educated in strict accordance with the inflexible doctrines of "Inductive Philosophy," constantly inferring and collecting general results, general facts, and laws, from a number of particular instances carefully established on actual Experimental evidence, this philosopher proved the utility of Chemistry when judiciously applied towards increasing the resources, and adding to the welfare of man;—demonstrated its importance as a medium for interpreting the wonders of natural phenomena;—

concentrated all its varied rays, by the mirror of truth, into one effulgent star of light, for the moral and intellectual guidance of man, towards "The First Author of Beauty who hath created them all."

God, for the fulfillment of His inscrutable purposes, has been pleased to take the spirit of this true philosopher to a better and more elevated sphere than the world that it was permitted for a few years to enlighten and adorn;—the voice that once poured forth fervid eloquence regarding the wonders of the Creation, is hushed, and the hand that demonstrated them, is closed in the silent, cold grave.

But those words of fervor, and works of skill, are faithfully remembered, and zealously guarded by his disciples who are yet permitted to remain; and as they follow at a vast distance the footsteps of their master, they endeavor, as he did, to keep the laborious yet certain path that is permanently illuminated by true experiment, and to shun the seductive uncertain mazes that are capriciously lighted by the false fires of theory and hypothesis.

In cases of doubt and indecision, reliance may always be placed upon the light of experiment, because its rays emanate from the rock of truth; theory and hypothesis "impose upon the imagination like the 'mirage' of the Egyptian sands, but like this illusion they must pass away; they may present to the eye a magnificence as seducing as the 'fata morgana' oftentimes witnessed on the coast of Calabria, in which the most beautiful landscapes, crowned with picturesque villages, superb palaces, and massy towers, seem to possess a real existence; all is but an aërial phantom; the enchanted scene changes with the least shifting of the light or the

ruffling of the sea;—melting away like a dream of the night; so, ultimately vanish all systems of Philosophy and Science that are not founded on the solid basis of Induction."

The fleeting form of clouds has been attentively studied by the meteorologist, and the refined instruments that are employed in such researches enable him to predict with considerable accuracy the probable state of the coming weather; although he yet remains in ignorance concerning the manner in which vesicular vapor is formed, or in which rain is relinquished from the clouds.

In the absence of accurate scientific knowledge, and refined meteorological apparatus, the husbandman invariably consults the appearance of the evening and morning sky, the actions of animals, the forms of flowers, and is thus enabled to foretell if the weather will be fair or foul.

The sky guides him according to the proverbs; and if, in the morning, cattle low more than usual, and stretch forth their necks, and snuff the air with extended nostrils, he expects rain; if the chickweed be quite open, and if the trefoil and bindweed stand out boldly, no rain will fall: many flowers besides these, close their petals against the approach of rain, but these are most common, and most easily observed.

The presence of watery vapor in the air, or more technically the "hydration" of the atmosphere, is imperatively requisite for the welfare of the animal and vegetable creation; animals cannot breathe, neither can plants grow, in dry or anhydrous air; their exquisite functions are immediately deranged, suspended, and ultimately destroyed.

The chemist has now to direct attention to the fact that absolutely pure water is a direct poison to aquatic beings, and for their respiration, the water they inhabit requires mixture with air, or aëration; precisely the same as the air in which we are placed, for our respiration, requires mixture with the vapor of water, or "hydration."

It has been already stated that pure water evaporates, and collects in the atmosphere as clouds; these by a recondite power, not understood, yield it back to the earth as showers. For the sake of illustration let us imagine that rain falls into a hollow or basin, near the summit of a mountain, and accumulates as an Alpine lake;—we ascend the mountain, and reach the lake, and then experience something more than mere bodily fatigue; our breathing becomes difficult, perhaps painful.

If we examine the water of the lake we find it either very scantily supplied with fishes, or entirely free from them. What is the reason of the oppression in breathing that we feel, and the fact regarding the lake that we discover? As follows:—the air is not so abundant upon the mountain summit as it is in the valley; it is more rare, more attenuated at this elevation, and therefore our lungs do not receive the supply to which they have been commonly accustomed, either in the valley, or on the level earth: the water of the lake, thus exposed to an atmosphere so rare, cannot exert attraction for it, or become sufficiently aërated to support the respiration of fishes.

Suppose even that aërated water were exposed at this great elevation, it would immediately part with its air, to supply the rarity of the surrounding atmosphere, as

t would to supply a vacuum: the following experiment can be made in illustration of this fact.

Place a large glass, filled with clear river or spring water, beneath the receiver of the air-pump, (page 118;) then exhaust the air from it as already directed; and it will be found that myriads of small bubbles will rise from all depths of the water; these were originally dissolved in it, and had no tendency to escape under the ordinary pressure of the atmosphere, but as the air is exhausted from the receiver, they are freed from pressure, and therefore expand and rise, and ultimately escape to supply the vacuum.

In place of allowing all the bubbles to escape, remove the screw, and admit the external air; its pressure will immediately force back those that remain into union again with the water, which will appear pellucid and clear as it did at first.

A portion of aërated water popularly so called, either natural, as Pyrmont-water, or artificial, as soda-water, after exposure to the air for half an hour, if similarly experimented upon, will evolve more numerous bubbles, than river or spring water; but such bubbles are not pure air, they are carbonic acid, formerly called "fixed air," in the one case, combined with water naturally by an unknown process, in the other artificially, by the force of machinery; but in both cases the sudden escape of the greater part of such carbonic acid when the corks of the bottles are drawn, causes the well-known effervescence; all does not escape, for at the end of half an hour sufficient remains dissolved in the water to present an effervescence when in a vacuum, and thus illustrates the point that we are considering.

If rain water be boiled, the air that it contained will be nearly expelled, and after allowing the water to cool down to atmospheric temperature in a tightly corked bottle,—if we pour it from this, without gurgling, into a finger-glass, and then introduce a small fish, it will show signs of distress by raising its head and gasping at the surface, and it would soon die if kept immersed; if it be removed, and the water poured from the height of two or three feet, from one vessel to another, for a few minutes, upon then immersing the fish it will not show such signs of distress as at first.

The water, on the one hand, contained no air for exciting the action of the respiratory organs of the fish, it therefore gasped to obtain a supply from the external atmosphere; but, on the other hand, by pouring the water for a time from one vessel to another, it became aërated, and fitted to yield a supply to the fish when introduced.

Fishes breathe in consequence of their respiratory organs being fitted to withdraw oxygen, not from the water itself, but from the air, that it is capable of dissolving and of holding in solution under ordinary circumstances.

The chemist applies these facts to the explanation of a natural phenomenon:—let us suppose that the unaërated, unproductive water of the lake overflows its bounds, and under the influence of gravitation dashes as a cataract over the mountain side; each moment that it increases in velocity, it passes into denser and denser regions of the atmosphere, and in the hurry and turbulence of its fall, dissolves air, foams with bubbles, and then flows onwards and throughout the valleys and plains, as a stream or river, sufficiently aërated for supporting the

espiration of aquatic beings, and accordingly we now ind them in abundance.

The description of this beautiful phenomenon may be ided by reference to the engraving, in which the hori- ontal shading being strong below, faint in the centre, and faintest at the top, may denote, as at page 123, that the atmosphere is heavy upon the level surface of the earth, light at some height above, and lightest at the elevation of the mountain summit.

Fig. 43.

Upon this, the unaërated water of the lake is supposed to be; and as it overflows and falls through the successive strata of the atmosphere, as indicated by the successive increase of the shading, it gains more and more air, until upon its arrival in the heaviest air, as indicated by the strongest shading, at the base of the mountain it becomes turbulent with foam.

The grandeur of a mountain torrent, cataract, or waterfall, is chiefly referable to the tremendous velocity of its fall in the denser regions of the air, and the powerful

shock with which the water and air incorporate, producing an enormous foam.

As such water traverses the surface of the earth in its return to the parent ocean, it widens its course and thus exposing a larger surface to the atmosphere, becomes more powerfully aërated, and likewise by the rippling the agitation, into which it is thrown by breezes and winds.

If we fill a vessel with water, thus naturally and wonderfully aërated, and place a fish in it, and then secure the mouth of the vessel with an air-tight cover, the creature will die when its respiration has consumed the certain amount of oxygen that the air contained; it will die though immersed in water that contains oxygen as an element, but this is combined with hydrogen, be it remembered, and the respiratory organs of the fish have not the power of separating it from such chemical combination, as they have from its mechanical mixture with nitrogen, which constitutes the chief volume of atmospheric air.

Fishes demand a constant supply of fresh aërated water, the same as animals demand a constant supply of fresh hydrated air, for both classes of beings are soon destroyed by the mephitic products of their own respiration.

The lavish abundance of air and water presented throughout Nature, would alone probably ensure the fulfillment of these demands for oxygen, and ages might elapse before either of these extraordinary media would become vitiated, or unfitted for the maintenance of life; but the Creator has made the same beneficent provision for purifying water from the results of the respiration of

aquatic beings, as He has made for purifying air from those of man and the higher order of animals.

Everything is miraculously balanced and adjusted throughout the Creation, and displays the power and goodness of God; and above all branches of science, that of chemistry is particularly favored in being permitted to become the medium of interpreting so many wonders.

During the bright weather of Summer and Autumn most plants that grow in ponds, pools and streams, and particularly those slender green filaments known to the botanist as "conferva rivularis," are covered with myriads of small air-globules; this is a common "observation;" the chemist devises means of collecting thousands of these globules in a glass, and finds that such aëriform volume will cause a lighted taper to burn with far greater brilliancy than it burns in the surrounding atmosphere: this is a simple "experiment;" he next reasons upon this, and, guided by "analogy," tries if all plants of a similar character, when exposed to light, will present the same phenomenon; he finds them to do so, and thus establishes a "scientific truth."

These three essential requisites enabled us to recognize the plants of the earth, combining their agencies for purifying the atmosphere from the mephitic results of combustion, and the respiration of man, and the higher order of animals; they will now enable us to recognize the plants of the water, combining their agencies for purifying it from the mephitic results of the respiration of fishes, and other aquatic beings.

When under the direct influence of solar light, the slender green filaments of "confervæ" have the power of decomposing the carbonic acid, produced by the re-

spiration of fishes, and of eliciting oxygen nearly pure; thus globules of this element, ascending and collecting in the glass, will support the flame of a taper with greater brilliancy than the surrounding atmosphere containing nitrogen.

Two or three handfuls of "conferva rivularis" collected carefully without injuring their fragile structure, may be introduced into a large globular glass "carafe," or "water-flagon," having a long and narrow neck—the narrower the better; then fill the "carafe" with water from the pool, pond, or stream, in which the plant grew; place one hand over the mouth of the "carafe" to close it firmly, and with the other holding the globular part invert it; pass the first hand beneath the surface of three or four pints of water contained in a shallow pan or glass; then withdraw it from the neck of the "carafe;" no water will escape from this, because the weight of such water is inferior to that of the surrounding atmosphere; thus the "carafe" will remain perfectly full, with its globular part containing the "conferva" uppermost.

As on account of the weight being so much above the narrow support of the mouth, the "carafe" would be liable to fall from this upright position, carry the arrangement to an open window where the sun is shining with its greatest splendor, set the pan upon the window-sill, place a heavy brick against the side of the pan to prevent it from slipping, and then gently move the "carafe" from its upright position—still keeping its mouth under water—that its globular part may securely rest against the corner of the window frame, as shown in the engraving on the opposite page.

This simple arrangement is precisely similar in principle, though upon a larger scale, to the well-known

Fig. 44.

"globe bird-fountain," that is placed in a "breeding-cage," or the "conical bird-fountain" that is placed outside, with its horizontal neck passing through a hole to the inside of a small bird-cage, and the "carafe" will act similarly to both of these contrivances.

For example, the water in each "fountain" is prevented from running out by atmospheric pressure; but as the birds gradually sip away the water from the "cistern" of the one, or the neck of the other, air will gradually bubble up into the globe or cone and cause the fall of an equal portion of water: as this is gradually drank, air will again gradually ascend, water will again descend; so that, at length, each fountain will be exhausted of water, or "dry," and will only contain air. The great utility of each contrivance is that only a very small surface of water is presented to the surrounding air, and therefore it cannot "dry away," or evaporate with the rapidity that it does from a wide shallow glass, or even from a common "bird-glass;" it remains as a refreshing store for the birds for many days without requiring replenishing.

These "bird-fountains," simple as they may appear,

and unworthy of attention as they may be thought, involve the principle upon which all the refined and accurate apparatus is constructed by the chemist for extending his researches regarding the nature of aëriform matters or gases, be they either invisible as Oxygen, or colored as Chlorine.

From facts, and contrivances the most simple, have emanated some of the most important and invaluable discoveries and inventions which adorn not only chemistry, but every other experimental science; but the pursuit of chemistry more particularly does not necessarily involve the possession of costly and complicated apparatus; SIMPLICITY, not mystery, is its aim, and by endeavoring to keep this steadily during our inquiry, we have been enabled, and shall yet be enabled to conduct many curious and instructive experiments with materials of common occurrence.

The splendid show of costly and beautiful apparatus that appears on the well-arranged table of the public lecturer, is imperatively demanded, because he has to demonstrate the facts of science to assembled hundreds; experiments therefore require to be made upon a large scale, with the greatest promptitude, and as far as possible with success, that all the audience may see, and may be simultaneously convinced of the facts under discussion, for the lecture-room is not the arena for individual instruction.

But in the quiet of the laboratory, much of the apparatus of the lecture-table may be dispensed with, and important facts discovered by simple means: thus the grand discovery of the element Oxygen, which, about seventy years since, completely changed the whole aspect of the science of chemistry, was made by em-

ploying a globular glass, or flask, about the size of that of the "bird-fountain," and inverted like it into a small "cistern," but instead of containing water, both vessels contained mercury, and in that of the globular glass was placed a portion of a compound from which, when heated by the rays of the sun in August, drawn to a focus in a powerful burning lens, Oxygen was at length evolved, and collected, as the air may be collected, in the "bird-fountain."

But in the arrangement with the "carafe," water, and "conferva," the artificial concentration of the heat of the sun is not required; its natural splendor alone is necessary; and after it has beamed upon the "conferva" for an hour, the slender filaments of the plant will be studded with beautiful globules of Oxygen; these gradually increase in size, and then either spontaneously quit the attraction of the filaments, or will do so upon slight agitation of the "carafe," and ascending to its upper part, there, after a few hours, by the addition of other globules which continue to rise, all will coalesce into one large bubble, a portion of water of corresponding volume having descended into the glass pan, this water being expelled by the oxygen evolved within, exactly as in the "bird-fountain" it is expelled by air ascending from without.

Allow the arrangement to remain exposed to the sun throughout the whole summer or autumnal day, to obtain as much oxygen as possible; kindle a very small wax taper attached to the end of a wire, as at page 67; then pass one hand beneath the water to close the mouth of the "carafe," and with the other lift it; and place it to stand upon the table, as the flask at page 66, and as in that the air ascended, so in this, the oxygen

evolved by the "conferva" will ascend and occupy the neck of the "carafe;" slide away the hand from its mouth, quickly introduce the lighted taper, and its flame will burn with far greater brilliancy than it did previously in the surrounding atmosphere. Why?

Because the carbon which first was an element of the living bodies of fishes, was converted into carbonic acid by their respiration, and so exhaled as a poison to them, but under the influence of light, the growing plants were enabled to convert it into nutriment for themselves by secreting the Carbon, and thus eliciting pure Oxygen; and there being no diluent Nitrogen present as in the atmosphere, there is no barrier or impediment to the intensely rapid combination of such Oxygen with the Carbon and Hydrogen of the taper, consequently its flame is greatly enhanced in brilliancy and swiftness of combustion.

The researches of the chemist warrant the conclusion that fresh-water plants, and likewise marine plants, derive the chief, if not the whole portion of their constituent carbon from carbonic acid, either absorbed directly by the waters from the atmosphere, or produced by the respiration of fishes; and thus both the vegetation of the earth and of the waters, may be equally active in keeping the just balance of the atmosphere for the life of man and animals, as for preserving their own proper degree of aëration for the support of aquatic beings.

The vesicles of the sea-weed, called "fucus vesiculosus," or more commonly "bladder-wrack," when recent, contain air more highly oxygenated than the atmosphere, and after having filled the "carafe" with water, and inverted it as directed, if several of these vesicles be punctured with a pin when immersed just below the

mouth of the "carafe," and then gently pressed, air may be collected from them, which will support the flame of a taper with greater brilliancy than the external atmosphere.

Such, then, are the simple experimental illustrations of the miraculous provision that is made in Nature for decomposing the mephitic results of the respiration of fishes, by the vital functions of plants; and it reveals to us another instance of the mutual dependencies of the two organic kingdoms. Fishes produce and exhale carbonic acid, growing plants, stimulated by solar light, decompose such compound, and increase their own structures by absorbing and combining with its carbon, emitting the oxygen, ready to dissolve again in the water, or to ascend to its surface, and there mingle in due proportion with nitrogen.

This mixture the water again absorbs, again its oxygen supports respiration, again carbonic acid is produced by the fishes, again this is decomposed by the plants, and from being mephitic it becomes a pabulum of life: thus incessantly does this wonderful action continue, and furnish a proof of the wisdom and power of the Almighty in providing for the welfare of His creatures.

It is necessary in the foregoing experiment to have the glass "carafe" as large as possible; indeed one of the globular "show-bottles" of a druggist's shop-window is preferable, if it can be obtained; plenty of "conferva" also is required; and if this cannot be easily procured, several bunches of "fresh water-cresses," or of "chickweed," may be substituted; and thus probably sufficient oxygen will be at length collected for proving its power of enhancing the brilliancy of the flame of the taper; but should there not be sufficient for this purpose, the fact of

the globules of the element appearing on the leaves of the several plants, will always be manifest in the bright sunshine.

We now discover the reason that fishes placed in marble basins or glass globes, filled with river water, so frequently become languid and sickly; they were taken from a pond or stream of water fully and powerfully aërated, and fitted for their respiration by the vital action of growing plants; they are suddenly transferred into a confined portion of the same water, and in proportion as they consume the oxygen of its aëration, they load it with carbonic acid, and no growing plants being present to decompose this, they must inevitably suffer in health, and will ultimately die if the water be not repeatedly changed.

It therefore becomes necessary for the life of fishes, in marble basins and glass globes, either to change the water repeatedly, or what is much better,—as selected from the perfect example of Nature, to introduce some aquatic plants, not only to decompose the results of the respiration of the fishes, but to afford them shelter from the solar rays; for these beautiful creatures demand such protection as imperatively as we ourselves; strange as it may appear, it is nevertheless a fact, that light-colored or silvery-white fishes especially, although in clear water, are sometimes scorched by solar heat.

A "silver fish" had long been the brilliant and spotless inhabitant of the clear water of a pond surrounded by lofty trees, casting shadows in which it could occasionally derive shelter from the direct rays of the sun; when these trees were ultimately cut down, and the waters thus exposed to the full unmitigated glow of light, the fish shortly appeared with a brown spot upon

its back, like a scorch; this increased in color and size, and according to the examination of a naturalist and physiologist, it was certainly a "sun-burn," but how produced?

As follows: solar radiant heat will pass through air, water, crystal, glass, or any other perfectly transparent substance, without imparting any portion of heat to them, but when the rays impinge upon solid opaque bodies, heat is immediately arrested and absorbed; thus the silver back of the fish was scorched by its solid tissue absorbing the heat that had passed throughout the water without elevating its temperature.

A direct experiment can be performed in proof of this curious fact:—obtain a very large "gold-fish-globe," wipe its exterior and interior perfectly clean, fill it with the most pellucid water that can be procured, place it to stand upon a sheet of white paper in the bright sunshine, and then with a large glass lens, or "burning-glass," collect the rays of the sun to a focus, (in a manner familiar to every schoolboy,) and direct this focus through the surface of the water in the globe; the transparent "burning-glass" will not become hot, neither will the transparent water into which its focus or "fire-place" falls;—as may be proved by the introduction of the bulb of a thermometer painted with white-oil paint, near but not in the focus.

If the opaque bulb touch the focus, then the radiant light and heat are immediately absorbed and converted into sensible heat, as the mercury of the thermometer will indicate by rapidly ascending in its tube; and if a very powerful lens be used, a piece of wood placed in the focus under water will be charred, or the hand even scorched; or other solid bodies be so heated, that the

water in contact with such surfaces will become warmed, convective currents will be established, and thus indirectly the temperature of the whole bulk will be raised, but neither directly by radiant heat, nor by conduction; of this latter more hereafter.

Again, remove the "conferva" or other plant from the "carafe," cleanse its exterior and interior thoroughly, fill it perfectly full of the clearest water that can be obtained; then tie a piece of well-moistened bladder closely over its mouth, and holding the neck, turn the globular part upwards; it will now, though full of liquid water, appear like a solid ball of glass; hold it in the sunshine, and move one hand about, at the distance of a few inches from the part of the globe opposed to that upon which the solar rays impinge, and a powerful focus of heat will soon be discovered, by the pain that the hand experiences; nay, this focus will kindle a piece of "German tinder," although the glass and the water remain cold.

Hence the danger of leaving globular "carafes" and "gold-fish-globes" perfectly filled with water, near window-curtains, papers, or "Lucifer matches," during a brilliant summer day; the position of the "carafes" and "globes" might be accidentally such as to direct their burning "foci" upon the inflammable materials; indeed this actually happened to a box of matches near a globular show-bottle of transparent liquid in a shop window.

These are a few of the curious discoveries that reward the investigations of the experimentalist, and they cannot fail to awaken his feelings of interest and admiration regarding the extraordinary powers and properties of matter; we must now turn to other things equally wonderful, and in many cases doubtless equally important, although

the exact part that they enact in the vast laboratory of Nature may not be as yet comprehended.

During Summer and Autumn, we may very frequently observe large air-bubbles spontaneously collecting, and bursting upon the surface of stagnant water; and if we disturb the mud beneath with a pole or rake, many thousands of such bubbles will quickly appear.

The Chemist has devised means similar in principle to those described, for collecting this exhalation, and upon analysis, he discovers it to be neither atmospheric air nor oxygen, but a gas composed of Carbon and Hydrogen, combustible, and burning with a yellow flame; in these respects it is identical with the "Fire damp" of coal mines, and closely analogous to the "Gas" obtained from coal for the purpose of artificial illumination; and therefore to denote that it contains the above elements, it is called "Carburetted Hydrogen."

The Chemist presumes this gaseous compound to be formed in stagnant water by the spontaneous decay or decomposition of its vegetable productions; and when it is kindled, either by lightning, or some unknown agent, it is probably the cause of the light that so frequently appears during Summer and Autumnal evenings, flickering and dancing over the surface of boggy and marshy soils, presenting the phenomenon called "Ignis fatuus," or popularly the "Jack-o'-Lantern," or the "Will-o'-the-Wisp."

In this country, the beautiful spontaneous light of the "glow-worm," and that of the common "hundred-legged worm" when irritated, are both popularly known; but in hotter climates the "lantern fly" and "fire fly" exhibit this luminous appearance in a degree yet more

nothing certain has been ascertained re
the phenomenon; it is probably refe
combustion of Phosphorus which these in
the power of secreting; as this light may be
rubbing the tip of "phosphoric p
"lucifer match" in the dark.

The decayed or "touch-wood" of old forest tree
observed to emit a pale light spontaneously
some kinds of fungi, if struck, as by the foot in wa
them at night; some flowers, as the tuberose
and marigold, occasionally present flash
light towards the close of warm evenings.

The chemist has not discovered the cause of
extraordinary phenomena, and therefore for want of k
ledge contents himself with denoting them unde
general title of "Phosphorescent substances."

Several animal substances are thus "Phosphores
when deprived of vitality, and long before their
commences; and of these the flesh of the
herring, sole, crab, and lobster, are the mo
luable; this phenomenon of luminosity is s
promoted by the dead flesh of quadrupeds, and
that of birds under any circumstances of putrefa

Water has frequently engaged our attention as a
agent in promoting not only the growth, but
the decay of vegetation; and this is
case when the element Nitrogen enters in
construction of organized structures.

The doctrine of the proper application of ma
substances, offers an illustration
of the economy of Nature, and
which it is arranged.

and decay of animal substances te

resolve organized forms into chemical constituents, or the peculiar effects discharged in the process, seem to point out the property of carrying them in the soil where they are first to perform the rôle of vegetables.

"The fermentation and putrefaction of organized substances in the free atmosphere are similar processes beneath the surface of the ground they are solitary operations.

"In this case, the food of plants is prepared which it can be used: and that vitiated vapour which offends the senses and injures the health if exposed, is converted by gradual processes into forms of beauty and of usefulness: the fetid gas is rendered a constituent of the aroma of the flower, and what might be poison, becomes nourishment to animals and to man."

It has long been familiar to physicians, that there is produced by wet lands, or by marshes and swamps, a poisonous and aërform substance, the cause not only of ordinary fevers, but of intermittents: and to this unknown agent of disease the term "marsh-miasma" has been applied; nor is such knowledge confined to physic: throughout the world it is a fact known to the vulgar and even to the less enlightened nations.

It is familiar to the rural inhabitants of Lincolnshire and Essex, who refer to the fens of these districts as the source of the agues under which they so commonly suffer; it is known to the rural inhabitants of certain districts of France, Holland, and Italy—in this last country more particularly—as "malaria;" it is also known to the uncivilized negroes of Africa.

The fairest portions of Italy are a prey to this invisible enemy "malaria;" the fragrant breezes are poison; the dews of its summer evenings are death; the banks of its

refreshing streams, its rich and flowery meadows, the borders of its glassy lakes, the luxuriant plains of its overflowing agriculture, the valleys where its shrubs regale the eye and perfume the air, are the appointed regions of this "malaria."

Death here walks hand in hand with the resources of life, sparing none; the laborer reaps his harvest but to die; or, he wanders amid the luxuriance of vegetation a sufferer from his cradle to his grave; aged even in childhood, and laying down in misery that life which was but one disease. He is even driven from some of the richest portions of this fertile, yet unhappy country; and the traveler contemplates at a distance, deserts, but deserts of vegetable wealth which man dare not approach or he dies.

Such is the picture of the noxious influence of these exhalations, which the Creator, for some inscrutable purpose, has ordained to reign in certain districts of this fair world.

This "marsh-miasma," or "malaria," often exerts its baneful power upon the husbandman in our country, at a time when his bodily strength and activity are most demanded for the pursuit of his labors; and therefore he devises all possible means for arresting its sway;—cutting down the vegetation,—removing the putrefying and corrupting mass,—sedulously draining off the stagnant water of marshes;—and thus he can occasionally improve the salubrity of districts within certain limits; but some districts are so extensive and so contaminated, as to defy amelioration by the utmost exertions of human foresight and labor, and they remain proverbially insalubrious.

In crowded cities and towns, where the buildings are

imperfectly ventilated, badly drained, and scantily supplied with water, if animal or vegetable offal be suffered to accumulate through indolence or neglect, and thus putrefy in the heat of Summer or Autumn, infectious or contagious matters are inevitably evolved or produced, and occasionally display their deadly powers in all the horrors of plague and pestilence.

The Almighty has not permitted the Chemist to discover the nature or the elements of such attenuated exhalations: they elude all detection; for if he take a volume of stagnant air from the foul "plague ward" of an Egyptian hospital, where crowds of livid and cadaverous beings are hourly stricken with the agonies of death, his analysis will prove it to contain the exact proportions by weight and by measure of elements and compounds, that are contained in an equal volume of a balmy breeze taken from a free and open English valley, where all are smiling with the inestimable blessing of health, and glowing with its bronzed and ruddy hues.

But the Almighty has mercifully permitted the Chemist to discover and to employ the power of destroying both contagious and infectious exhalations, and of thus averting within certain limits, the dreadful judgments of plague and pestilence.

From the atmosphere itself, the Chemist is permitted to produce a compound, and from the salt of the ocean, to elicit an element for destroying contagion and infection; these miraculous compound and elementary gifts, have been already mentioned under the respective titles of Nitric acid and Chlorine.

Nitric acid is a compound of Oxygen and Nitrogen, this latter term implying "generator" or "producer"

of Nitre, because the continued passage of electricity through a portion of air, contained in a vessel also holding a solution of potash, eventually produces crystals precisely resembling in shape and composition those of native Nitre, or "salt-petre," which, consisting of Nitric acid and Potash, is called Nitrate of Potash.

This extraordinary compound is abundantly presented in a crystaline form by certain soils of oriental countries, and the Chemist can obtain Nitric acid from it with much greater facility and in larger quantities than he can do by exciting the direct union of the elements of the air by electricity; but he is led to conclude, that the word Nitre, as it occurs in Scripture, does not denote the compound now under consideration, and the following are the facts which lead him to this conclusion.

"Though thou wash thee with nitre, and take thee much sope."

And again;—"As vinegar upon nitre, so is he that singeth songs to a heavy heart."

Nitre, salt-petre, or Nitrate of potash, is unfit for employment as a detergent in washing, neither will it form a soap;—and vinegar poured upon it produces no remarkable effect; but another crystaline product of the earth, closely resembling it in appearance, is here to be understood by the word Nitre, viz., a natural compound of Carbonic acid and Soda, a Carbonate of soda, which dissolves in a very small quantity of water; and such solution is used for washing in many parts of Asia, and when mixed with oil it forms soap; the crystaline substance itself, from these two circumstances, and being abundantly found in Egypt and various parts of Asia, is called "soap-earth."

Upon this "soap-earth," or Carbonate of Soda, if

Vinegar be poured, the two substances are found incompatible with each other; a foam or effervescence of Carbonic acid is immediately expelled; and as vinegar was well known in the remotest ages, the fact of its action upon ancient nitre, or "natron," or the fact of the opposition between the two substances, is taken as the foundation of a beautiful and powerful metaphor for illustrating the equally extreme incompatibility between songs and a heavy heart.

Probably the term Nitre was applied to both nitrate of potash and carbonate of soda, from the circumstance of their simultaneous occurrence in eastern countries, and their mutual resemblance in appearance when extracted in a crude state from the earth.

The chemist discovers that an acid called sulphuric acid to denote that it contains more oxygen than the sulphurous acid with which the flowers were bleached at page 102, is as perfectly incompatible with the Nitre of nitrate of potash, as is the vinegar or acetic acid with the nitre of carbonate of soda; and when sulphuric acid and nitrate of potash are mingled together in a saucer, and a moderate heat applied, that the sulphuric acid combines with the potash, forming a sulphate of potash, and expels the Nitric acid in fumes combined with water that the former acid contained. Thus making the experiment in an infected atmosphere, with a sufficient quantity of materials, the hydrated fumes of the nitric acid will destroy the mephitic matters.

Sulphuric acid frequently occurs native, particularly in the lakes and waterfalls of volcanic districts, but it is artificially formed in the chemical laboratory by burning sulphur mingled with nitre in air, and thus by the intervention of the oxygen contained in the Nitric acid of the

Nitre, the fumes which would otherwise be only sulphurous acid, are incited to combine with more oxygen, and become those of sulphuric acid, which immediately dissolve in the water that is simultaneously presented.

Salt, which is the great natural source of the element chlorine, may be obtained from the water of the ocean, or from that of brine springs, by exposure of either in large shallow pits to the evaporating action of solar heat, or in pans to the vaporizing agency of artificial heat applied beneath, as in ordinary boiling; in both cases the solid fixed salt will remain.

Both processes are conducted upon a gigantic scale for supplying salt, which is an essential addition to the food of man and animals; it is therefore most lavishly presented, not only in the waters of the ocean, or of brine springs, and thus requiring an amount of chemical knowledge for its extraction, but as a solid crystaline deposit of vast extent in the strata of the earth, and only demanding mechanical labor for its "getting."

This variety of salt is called "rock-salt," to denote its native, hard, and solid state, whilst the two varieties already named are called "sea-salt," and "bay-salt," he latter term denoting the vessel technically called "a bay," in which the brine is pent up, or subjected to the action of heat, or to denote that it was formerly caused to form a small "salt-bay" over a certain tract of land for spontaneous evaporation to ensue.

Rock-salt is quarried like stone in large crystaline masses, sometimes pure, colorless, and transparent as ice, at others variously colored by native metallic compounds, or contaminated to a considerable extent by sulphate of lime, or gypsum; this last variety of rock-salt, upon exposure to moist air, will soon lose its actual saline matter,

or chloride of sodium, by the solvent power of the watery vapor, which, having no such action upon the gypsum, that will remain solid and devoid of taste.

A natural analysis, or separation of the common-salt from the gypsum, is thus effected, similar to the artificial analysis or separation of the salt from the sand in the experiment at page 53, and knowledge of these facts enables the Chemist to venture upon an interpretation of the following Scripture passage, in which, as in many others, allusion is made to familiar things in order to convey important truths to obdurate minds.

"If the salt hath lost its saltness, wherewith shall ye salt? It is fit for nothing but to be cast out, and trodden under foot."

In this case the salt, from its universal employment as a savor to food, being the valuable, and the gypsum, from its inapplicability to such purpose, being the comparatively worthless portion of the compound mineral product.

"Can that which is unsavory be eaten without salt? or is there any taste in the white of an egg?"

This passage evidently proves that the use of salt as taken with food, to confer flavor upon it, was known in the remotest ages, but the reason of its utility in entering from food into the constitution of the blood, and likewise its own composition, have only been determined of late years; the fact as regards composition most concerns this inquiry.

Unlike Nitric acid from Nitre, Chlorine cannot be directly educed from salt or chloride of sodium, but by the action of sulphuric acid, a produce or compound can be obtained, from which the chemist can educe the element

of which he is in search, and employ it as a disinfecti agent.

Place about a quarter of an ounce of salt in a sauce and pour upon it twenty or thirty drops of sulphur acid; dense white fumes will immediately arise, pr cisely similar in appearance and chemical compositio to those which destroyed the geranium or myrtle at pag 101, and having an equal destructive power upon suc or other plants; these fumes were called hydrochlor acid, and by peculiar management, when dissolved i water by the chemist, they constitute the hydrated liquid hydrochloric acid with which the experiment wa made.

Salt has been repeatedly spoken of as a chloride sodium, why then does hydrochloric acid, a compoun of chlorine and hydrogen, appear from salt that contai no hydrogen? As follows: although the salt contain no elements save chlorine and sodium, the sulphuri acid contains water, and Water contains both Hydro gen and Oxygen: accordingly, during this apparentl simple experiment, a refined chemical change ensues; th sodium of the salt unites with the oxygen of the wate to form oxide of sodium or soda, and this directly unite with the real sulphuric acid to produce sulphate of soda whilst the chlorine that was with the sodium, but now emancipated, combines with the hydrogen that was with the oxygen; and thus the two elements, Hydrogen and Chlorine, produce Hydrochloric acid; the result is a pro- duct, not an educt.

Rub a quarter of an ounce of Salt with half an ounce of "Red-lead," *i. e.*, an oxide of lead, to fine powder; place this in an ale-glass; slowly add a teaspoonful of sulphuric acid to a teaspoonful of water contained in a

gallipot; and when this diluted acid is cold, pour it nto the ale-glass, stir it with a piece of stick; and now, n addition to sulphate of soda, as in the last experiment, a portion of sulphate of lead is formed simultaneously with hydrochloric acid, but this acid is immediately le-hydrogenated by a part of the oxygen of the original oxide of lead; water is formed, and then Chlorine is truly educed, in the state of a yellow vapor which arises in the glass.

For the purpose of fumigation, the chemist generally prefers to educe Chlorine from a compound well known as "Chloride of Lime"—more correct would be the expression "Chlorinated Lime:" this compound has the invaluable property, when exposed to an infected atmosphere, of slowly evolving chlorine, which, mingling with mephitic matters, deprives them of virulence more effectually than even the action of nitric acid.

The simplest method of proceeding to fumigate a small apartment is to select ten or twelve earthenware flower-pans, and place in each of them six or eight ounces of chlorinated lime; then arrange these pans, some near the ceiling, others near, or upon the floor; then close the doors and windows, and leave all undisturbed for a day or two, in the course of which time he carbonic acid of the air will have expelled much of he chlorine from the compound; the windows of the partment must then be opened from the outside, and resh air allowed to sweep through previous to opening he door, for many persons are seriously affected by a ery slight inhalation of chlorine; the chlorinated lime ay be then stirred in the pans with a piece of stick, nd again left shut up for a similar time.

The whole of the chlorinated lime may next be put

into one large deep pan, much larger than is sufficient to hold it; this is to be placed on the top of a pair of steps, so as to be near the ceiling, and then, having shut the windows, quickly pour about a quart of vinegar into the pan, and immediately quit the room, closely shutting the door.

The affusion of the vinegar will now liberate all the chlorine that the compound might yet contain, and after a day or two, the room may be entered with the above precautions, and the residue in the pan carefully thrown away.

In extensive fumigations, chlorine is generally evolved from a mixture of four pounds, by weight, of common salt, one pound of oxide of manganese, two pounds of sulphuric acid, and two of water; no precautions are required for mixing the two former, but great precautions are required as regards the two latter.

The water must be placed in an earthenware bowl, and then the sulphuric acid must be added in a very slender stream, the mixture of the two liquids being rapidly promoted by stirring them together with a flat piece of wood; it must then be allowed to cool before use.

If sulphuric acid be plentifully and suddenly added to water, the heat evolved by the meeting of the two cold liquids is so great that it will inevitably break a glass vessel, and very likely one of earthenware:—why is the heat evolved?

Because the water, which is the lightest liquid of the two, when it energetically combines with the sulphuric acid, has its density increased, and therefore its capacity for heat diminished in a far more remarkable degree than in the experiment with water and spirits of wine, as

etailed at page 115, and most dangerous accidents have appened to persons in ignorance of this fact.

The mixture of common salt and oxide of manganese nust then be weighed into five portions of one pound ach, and placed in as many quart or three pint earthenware basins upon the five topmost "treads" of a pair of steps set in the centre of the room, the windows being closed; then, with a half-pint jug dipped into the cold diluted acid, a quantity of it sufficient to fill about three parts of the jug must be baled out and poured upon the mixture contained in the uppermost of the pans, then a similar quantity upon that in the second, third, fourth, and fifth, as quickly as possible, the operator always taking care to avoid placing his face, either level with, or below the pans; this he can do by standing on another pair of steps, more elevated than the first, and placed close alongside; he must then quickly descend and quit the apartment, shutting and securing the door.

Should any chlorine be accidentally inhaled, the readiest means of alleviating the distressing coughing that it produces, is to saturate a lump of sugar with brandy, and a few drops of "sal volatile," and then to hold the sugar in the mouth until it dissolves.

The basins may remain for two days, then the windows of the apartment being opened from the outside, as already directed, when the odor of chlorine is no longer strongly perceptible, the apartment may be entered without danger, the basins removed, their exhausted contents thrown away, and then they may be again charged and arranged with all former precautions, and left for a similar time, and subsequently removed with the same careful observance.

The apartment may then be considered to have undergone a thorough fumigation, for neither infectious nor

contagious matter can insidiously lurk in the presence of chlorine.

The pans containing the "chlorinated lime," and the basins containing the mixture of which mention has been just made, are directed to be placed near the ceiling of the room, because the evolving chlorine is more than twice as heavy as the air, and therefore will descend and uniformly mingle with it, which is the grand object of the whole proceeding; if, however, the vessels were placed on the floor, the heavy chlorine would chiefly repose there as a distinct stratum, and not rapidly diffuse its powers throughout the main volume of the air.

The precaution to be observed by the operator, in proceeding quickly with the addition of the acid, and in keeping his head above, and not at or below the vessels, is, in the first place, that the evolution of chlorine may commence from all within a few seconds, and in the next, that he may avoid inhaling any portion of the descending poisonous element, for a poison it is, although applied for the destruction of another poison; if he can hold his breath during the few seconds that are required for the addition of the acid and his descent from the steps, it will be so much the better.

The chemist, therefore, discovers an extraordinary fact in illustration of the power by which elements and compounds are controlled, viz., that chlorine in its pure uncombined state is a poison, and a destroyer of poison, whilst in combination with the metal sodium; it forms exactly sixty per cent. of the common salt, which is an absolute requisite of life, and a most powerful antiseptic of organic matters.

The yellow color of chlorine, its density, its power upon organic and inorganic bodies, may be demonstrated

by the following experiments, which should be made in the open air, that the deleterious vapor may be instantly wafted away.

Place two ounces of "chlorinated lime" in a pint wide-mouthed flint-glass bottle, then quickly add a fluid ounce of "hydrochloric acid;" an evolution of chlorine will immediately ensue; it will expel the air from the bottle and supply its place with its own yellow vapor, which is now technically said to be the "atmosphere of the bottle;" the yellow will become yet more visible if a sheet of white paper be held behind one part of the bottle.

Immerse a few shreds of red cabbage leaves in a tea-cup half full of boiling water, and thus obtain a fine blue-colored infusion, which, when cold, pour into a tall half-pint ale-glass; then take the bottle containing the chlorine, and holding its mouth over that of the glass, as in the ordinary act of pouring, the heavy chlorine vapor will pour out like water, and not only display its color in the glass, but upon slight agitation it will instantly destroy that of the blue vegetable infusion.

If a piece of tainted meat be placed in a half pint wide-mouthed bottle, provided with a glass stopper, upon pouring chlorine into it, then closing it, and leaving the meat exposed to the vapor for half an hour, upon shaking it out the taint will be destroyed.

Twist a piece of thin copper bell-wire into a tolerably close spiral around a ruler, then place two leaves of "Dutch gold" (*i. e.*, nearly pure copper), within this spiral; put half an ounce of "chlorinated lime" into a half pint ale-glass, add half a fluid ounce of hydrochloric acid, cover the mouth of the glass with a card until the chlorine appears deep yellow; then quickly remove the

card, and introduce the spiral; the leaves of metal will instantly kindle and burn with a vivid red light, thus affording an example of combustion without oxygen, and manifesting the intense affinity of chlorine for the metal, with which it forms artificial "chloride of copper," as with sodium it naturally formed "chloride of sodium," or common salt.

Such, then, are a few of the important applications of chlorine as a disinfecting agent, and its intense chemical powers upon other matters.

The mere burning of incense or pastils, sprinkling "eau de cologne," lavender water, or vinegar in an apartment, will only cover an unpleasant odor, and will not destroy the virulent matter of which it consists; so burning feathers on a heated shovel, or stirring a basin-full of vinegar with a red-hot poker, although certainly fumes arise in both cases, and such operations are therefore esteemed "fumigations," they are worthless as disinfectants: the mephitic matter remains in full force, disguised, but not destroyed.

Solar heat never gains sufficient intensity to destroy infectious and contagious matters, but, on the contrary, its natural range under the conditions already stated, is rather an active agent in exciting their production; an artificial heat of 220 degrees, on the other hand, is sufficiently intense to destroy them most effectually, and accordingly articles of wearing apparel, bedding, blankets, curtains, draperies, &c., which might be injured in color and texture by the powerful action of nitric acid or chlorine, may be disinfected by hanging them in a room heated by an open fire of charcoal in a brazier, the operator taking care not to remain in the room or to enter it until fresh air has been allowed to

sweep through, to remove the poisonous vapor of carbonic acid that is invariably produced by the combustion of charcoal in air.

Woolen goods are especially retentive of contagious and infectious matters, and in all doubtful cases they should be burnt without the slightest compunction or hesitation.

The action of artificial or fire-heat upon infected air in disarming it of mephitic power, was well known to our forefathers, who, during the awful times of plague and pestilence, kindled huge piles of wood or large tar-barrels in the streets of cities; such fierce combustion demanded an enormous volume of air for support, and as it rushed forward, loaded with disease, it became partly heated, partly consumed, and swiftly mounted to higher regions, whilst a strong draught was created through the streets, and eventually drew purer air from the suburbs.

When the equilibrium of the atmosphere is thus disturbed by an extensive combustion, the draught that is produced is of extraordinary power; this was exemplified during the burning of Moscow; it is said that the wind, naturally high, was raised by the sudden rarefaction of the air, to a perfect hurricane; the howling of the tempest drowned even the roar of the conflagration.

In time of plague, the inhabitants of cities resorted to the vicinity of iron furnaces, metal foundries, and other works emitting fumes of sulphureous acid matters; these and the high temperature neutralized or destroyed the mephitic portions of the air, for infection in such situations was but rarely taken. The vapor of burning sul-

phur is still used in the East against the plague, but its power is feeble in comparison with that of chlorine and nitric acid.

Another powerful adjunct in cases of fumigation, is quick-lime; when the apartment has been subjected to the agency of chlorine or nitric acid vapor, if practicable, the walls, ceiling, and floor should be lime-whited, the lime by its extreme causticity removes all adherent organic matters; mere white-wash is useless, because it is made of whiting or carbonate of lime, a perfectly neutral compound, having no power upon organic matters.

Lime-white is active because it is made of quick-lime, which is known by its cracking and becoming very hot when slaked with water, and when mixed with sufficient water, it should be employed immediately, otherwise it will absorb carbonic acid from the air, and form carbonate of lime, which has no caustic property.

The chemist can neither isolate the above mephitic exhalations, nor the aroma of plants and flowers from the atmosphere, although he is tolerably certain that abundance of such attenuated matter must be contained therein at various seasons; thus, for example, the flowering of beans frequently loads the air with an insupportable fragrance, and such vegetable perfume is retained by the air with great and persistent force, and wafted by its winds occasionally to extraordinary distances: it is stated that the fragrance of cinnamon, which is abundant in Ceylon, and that of the rosemary, growing on the coasts of Spain, has been distinctly perceptible to persons at sea, even when distant five miles from those shores.

It must always be borne in mind that the atmosphere is not an immovable volume of gaseous and vaporous

constituents, but that it is continually in motion through convective currents into which it is thrown by the agency of heat, and if it be rarefied or attenuated in one locality, air that is more dense instantly advances to restore the equilibrium.

Take a familiar example,—we kindle a fire in the grate, the air contained in the chimney is immediately rarefied, it ascends, whilst dense air rushes through every crevice of the room to restore the equilibrium, and produces a draught.

When disturbances in the equilibrium of the atmosphere naturally ensue through the influence of solar heat, they are recognized as breezes and winds, and they tend most effectually to disperse the mephitic matters resulting from the decay of organic productions and from respiration and combustion throughout the enormous volume of the atmosphere, in a state so highly attenuated as to be rendered harmless and even to elude detection.

During the Four Seasons, we have ample opportunities of experiencing the physical force of atmospheric motion in every degree; for example, the gentle zephyr floating the thistle-down, and undulating the corn; the fresh breeze rippling the surface of the stream, and swelling the canvas of the bark; the tempest blast lashing the ocean into waves and appalling the heart of the mariner; and lastly, the fierce hurricane, uprooting the oak of the forest, devastating the harvest of the plain, and overwhelming the works of man with ruin and desolation.

With few exceptions, during Summer and Autumn an extreme closeness, or oppressive heat, an extraordinary transparency of the atmosphere, an unusual tranquillity

of the animal and vegetable kingdoms, and a painfully acute sensibility of the human ear to accidental sounds, may be regarded as certain forebodings of an approaching "thunder-storm."

This awful and astounding phenomenon is still ordained to be an occasional visitant of the terrestrial atmosphere, as it was in the remotest ages, when the Psalmist, extolling the power of the Almighty, records that "the clouds poured out water, the air thundered, and Thine arrows went abroad. The voice of Thy thunder was in the heavens, the lightnings lightened the world: the earth trembled and shook."

In his limited endeavors to reason upon, and, if possible, to explain, the physical cause of a phenomenon so wonderful and terrible as the thunder-storm, the chemist discovers by experiments, that in the generality of cases, either sudden or extensive changes, regarding either the physical or chemical forms of substances, are attended by the display of the imponderable agency of Electricity.

Throughout the whole of this inquiry regarding the Four Seasons, it has been remarked, that an enormous change of water from the state of liquid to that of vapor, is constantly proceeding from every aqueous portion of the entire globe, and to such physical change, the chemist refers with extreme probability the immediate cause of the thunder-storm; for he discovers that the artificial conversion of water into vapor always develops Electricity, and, under certain conditions, develops it with the striking concomitants of vivid light, intense heat, and snapping sound, differing only in degree from natural lightning and thunder.

The chemist, by his artificial excitation of Electricity,

can cause its spark to accumulate in intensity and power, can direct this for the fusion and combustion of metals, the paralysis or death of organic bodies, and thus imitate, upon a microscopic scale, the well-known effects of the resistless flash of lightning from the heavens.

He discovers that substances, having a redundance of electricity, or being charged with electricity, invariably endeavor to communicate or to discharge it to others that are deficient, and when this restoration of equilibrium or discharge is suddenly and extensively effected, it is attended by intense heat and vivid light.

Further experiments inform the chemist, that such restoration of the equilibrium or discharge of electricity, may be either arrested, opposed, or facilitated by several distinct substances; or, as in the case of Heat so in this of Electricity, there are non-conductors, bad conductors, and good conductors.

Anhydrous air is a non-conductor, earthy substances are bad conductors, water and metallic ores are better conductors, and pure metals the best conductors of imponderable Electricity.

The greatly desiccated atmosphere of Summer, and of the first days of Autumn, though not an absolute non-conducting, is an extremely imperfect conducting medium of electricity; and this agent, by some recondite property, appears to accumulate in the atmosphere, probably during the incipient condensation of its watery vapor into the mysterious form of clouds; these clouds are regarded as aqueous volumes highly charged with electricity, floating in the vast and generally desiccated volume of the air; or, in other words, a volume of dry air, capable of supporting the clouds, yet incapable of depriving them of their electrical charge.

The clouds endeavor to discharge this electrical surplus to the solid earth and flowing waters; the air will not conduce to this effort, and eventually the surplus or accumulation in the clouds is so excessive, is so powerful, that it suddenly pierces or disrupts the air by a flash of lightning to the earth and waters.

This lightning is succeeded by thunder, a sound produced by the immediate and violent collapse of the disrupted air, to effect the restoration of its own equilibrium; "like as when an arrow is shot at a mark, it parteth the air which immediately cometh together again, so that a man cannot know where it went through."

The time which elapses between the flash of lightning and the explosion of thunder, affords the means of calculating the distance of the storm, for light, moving with the incomprehensible velocity of 192,000 miles in a second, the time that it takes to traverse any terrestrial distance may be considered as nothing, but sound travels only at the rate of about 380 yards in a second.

The flash and the thunder are really simultaneous, but the former is instantly seen, whilst the other requires a second of time to traverse 380 yards; therefore the interval that elapses between the two phenomena, being multiplied by this number, will give the distance of the storm.

Thus, if the flash take place six seconds before the thunder is heard, then $6 \times 380 = 2280$ yards, or one mile, two furlongs, and eighty yards, which is the distance of the storm from the observer.

Let it be particularly remembered, that this calculation regards a discharge of lightning that has happened, and it must not be considered as a measure of the removal of the observer from danger, for other discharges may

rapidly happen much closer, as thunder clouds are frequently extended over a great extent of terrestrial surface, and very frequently two or three flashes of lightning are seen, apparently simultaneously, in the different parts of the atmosphere.

When lightning flashes in a long, irregular, angular, gnarled or knotted stream, these appearances announce its passage through an extensive volume of the atmosphere; but when it flashes in a short, straight, or direct line of vivid light, it may be considered to have disrupted a comparatively limited portion of the atmosphere.

In the first case the flash would be seen some time before the thunder would be heard, and in the second case the flash would be instantly followed by the thunder.

Fig. 45.

The tree in the background is supposed to have determined the discharge of lightning from a cloud hovering at a considerable distance; the flash is therefore long and irregular; and a spectator of the storm, if standing near the tree, would first hear the thunder from the collapse of the air near its summit, then from beyond this, afterwards from a more remote portion, and ultimately from the volume of the cloud, whence the light-

ning first broke forth; the thunder, therefore, would not fall upon the ear as one direct and crashing sound, but as an irregular succession of sounds, or loud rumbling noise.

"This irregularity in the passage of lightning is sometimes so considerable, that the thunder is actually lost to the ear at one moment, and heard again at another, and this three or four times successively in the same clap;" and this, conjoined with the reflection of the sound, or its reverberation from mountain, hill, and valley, at one instant pealing loudly, at another, booming gently, at length murmuring faintly, and ultimately dying away, are extremely impressive concomitants and attendants of the original phenomenon of the flash.

The tree in the foreground of the engraving, is supposed to have determined the discharge of lightning from a cloud hovering at a little distance, the flash is therefore short and regular, and a spectator of the storm, if standing near this tree, at the moment of the flash, would hear the full thunder of the collapsing air, as one loud and terrible crash, which in a few seconds after, would reverberate from surrounding objects, and ultimately die away in silence.

When the chemist causes electricity to pass through large and small intervals of air, the vivid sparks in their disruptive transit, present upon a microscopic scale appearances precisely similar to those of extensive and limited flashes of lightning.

An appearance of two distinct flashes or streams is very frequently produced at a considerable distance from each other, when part of a long, sharp, angular flash is hidden by an intervening cloud, and the sudden

and universal flash, or "sheet lightning," appears to result from a discharge which is more perfectly concealed.

The bright flashes which occur during summer and autumnal evenings, unaccompanied by thunder, are of this kind, and it is supposed that on account of their vast distance from the earth, that the sound of the thunder must be lost in its passage.

"The appearance of the heavens during a thunderstorm, the manner in which the clouds assemble, and attract and repel each other, the circumstance of their rising against the wind, and traversing the upper regions of the atmosphere in a variety of contrary directions, are phenomena which it is not difficult to explain by reference to the general laws of electricity."

Many of these have been discovered by the great philosopher of the present day, and regarding his extraordinary knowledge of Electricity and Chemistry, it has been justly said, that, "in point of originality in devising experiments, skill in carrying them into effect, and perspicuity in tracing out and unraveling the complicated relations of the new truths which are elicited, he stands, if not unrivaled, at least unsurpassed."

Upon known laws of electricity, as excited in the laboratory, the peculiar fringed appearance of a thundercloud may be explained, and also the irregular portions which it projects towards the earth, whilst its upper surface is generally smooth, and well-defined.

"We sometimes observe that a number of such clouds of small dimensions, coalesce into a larger one, moving swiftly in all directions, and darting flashes from one to the other, whilst the wind rises and often blows in squalls; the lightning is more frequent as the clouds aggregate,

and a great expanse of the heavens often appears in an almost continuous blaze of light; the thunder at first rumbling in the distance, now approaches with various roaring and rattling sounds, and the rain often falls in torrents.

"If we watch a severe thunder-storm from the beginning to the end, we observe a singular variety in the appearance of the flashes; the scene is sometimes rendered awfully magnificent, by their brilliancy, frequency, and extent, darting sometimes in broad, well-defined lines from cloud to cloud, and sometimes shooting towards the earth, they are often zigzag and irregular, and sometimes are said to appear as a large and rapidly-moving ball of fire, an appearance usually designated by the uninformed, 'a thunderbolt,' and erroneously supposed to be attended by the fall of a solid body."

Thus the nodular masses that are so frequently found on the sea beach, at the foot of chalk cliffs, are called "thunderbolts," yet they have not fallen from the heavens, but from the cliffs, and when chemically examined, are found composed of sulphur and iron; they are "sulphurets of iron," therefore, and if two masses be violently struck against each other, sparks of fire appear, in consequence of the heat of the blow or collision having enabled both elements to attract oxygen from the air and burn; thus fire was anciently obtained, and the name of "pyrites," or "fire-stone," was likewise conferred upon the supposed "thunderbolt." But let us continue our investigation of the "thunder-storm."

"The voice of the Lord is upon the waters: The God of glory thundereth: The Lord is upon many waters."

"The voice of the Lord is powerful; the voice of the Lord is full of majesty."

In such sublime and rapturous exhortation to the princes of the earth, does the Psalmist set forth the glory of the Omnipotent Ruler of the storm; and regarding its awful and astounding grandeur, no man can either feel, or feign indifference; yet he does well, that instead of indulging in morbid fear, and of communicating it to others, endeavors to calm such emotions, by reflecting and expounding that the will of God directs the storm, to remind us of our insignificance, which, in the pride of our knowledge, and the height of our abundance, we are but too prone to forget.

It is, however, the imperative duty of every man to exercise his utmost reasoning and inventive faculties for guarding his life, and the lives of others, against the physical power of the lightning, and not with impiety and presumption to defy the storm.

In the open air, shelter should not be sought immediately under a tree or building, for should they be struck, such a situation is particularly dangerous, if not fatal; the distance of twenty or thirty feet from tall trees, or lofty buildings, is, on the contrary, an eligible situation; for should a discharge take place, these prominent bodies are most likely to receive it, and the less elevated bodies in their vicinity may therefore escape uninjured.

It is quite essential, during a thunder-storm, to avoid every considerable mass of water, and even the streamlets that may have resulted from a recent shower; for these are all excellent conductors, and the height of a human being when near them, might probably determine the discharge of lightning; shelter under the arch of a bridge is a comparatively safe situation.

The conductors and imperfect conductors through which lightning directs its course when it strikes a building, are generally the metallic appendages of the walls and partitions; the most secure situation is therefore in the middle of the room, especially when standing on a hair mattress, or even a thick hearth-rug; and if a bed be drawn into the middle of the room, it will afford perhaps the safest of all situations.

The part of every building least likely to receive injury is the middle story, as the lightning does not always pass from the clouds to the earth, but occasionally from the earth to the clouds, a phenomenon called the "returning stroke;" hence it is useless to take refuge in the lowest story or in a cellar.

Many instances are recorded in which the basement story has been the only part of a building that has sustained severe injury, the lightning being weakened as it ascended.

Whatever situation be chosen, any approach to the fire-place is most dangerous; for the heated air, or even the soot in the chimney, are conductors sufficiently good to determine the course of the lightning flash, especially as they are in immediate connection with the excellent conducting iron work of the grate, fender, and fire-irons; the same caution is necessary with respect to gilt furniture, bell-wires, and moderately extensive metallic surfaces of every description.

It is likewise exceedingly dangerous to approach a window for the purpose of closing its shutters, if they have large iron bars or bolts for fastenings; an instance is known of a shock having been suddenly experienced by a female endeavoring to bar a window during a severe discharge of lightning; the effect lasted a considerable

time, but fortunately did not prove fatal. In a carriage, the precaution of keeping at some inches distance from its sides or back is also advisable.

These particulars have been enumerated from a desire "to supply what useful information the present state of our knowledge may afford, and to diminish that anxiety and fear by which the minds of many are oppressed during the occurrence of these magnificent but awful phenomena."

The operation of mysterious agents has always considerable effect on the human mind; and by raising a host of unreal terrors, may suspend the action of its best energies; but when we are enabled to ascertain something regarding the nature and influence of the powers which surround us, we are prepared to meet their effects with feelings equally remote from vain confidence and useless fear; and are thus enabled to avoid their dangers effectually and without agitation.

"Where persons have been killed by lightning, it has generally come upon them so suddenly as to leave no time for precaution; though it must also be admitted that some have suffered from foolishly ridiculing the idea of danger, and wantonly exposing themselves to the storm, walking out to admire its grandeur, or insisting upon opening the windows to look out and observe it, or standing under a tree for shelter.

"A severe thunder-storm is always an awful and dangerous phenomenon; and while, on the one hand, it is the extreme of folly to neglect common precaution, or to ridicule those that are alarmed, it is, on the other, equally weak to give way to unfounded apprehension."

As the important discovery of Oxygen was made by the employment of the simple form of a "bird-fountain,"

so the astonishing discovery of the identity of lightning with electricity was made by the use of the still more simple means of a common kite; and it likewise proves that men must condescend to attend to the most ordinary things if they would acquire knowledge, for the design of philosophy is "not to build a capital, or erect a pyramid, to the glory of man, but to found the temple of the universe in the human intellect."

At a very early period of the Science of Electricity, experiment had shown that electricity is attracted by points, and if highly excited, it discharges itself with a flash and report; lightning and thunder exhibited an example of a flash and report;—the atmosphere was known to be susceptible of electrical influence;—all this had been ascertained, but no relation had been established between the cases;—other causes might possibly produce a flash and report;—but the analogy of electricity presented itself strongly to the mind of a true philosopher, who reasoned thus:—"The electric fluid is attracted by points; we do not know whether this property be in lightning, but since they agree, in all particulars in which we can already compare them, it is not improbable that they agree likewise in this."

"Let the experiment be made."

He made the experiment, by attaching a pointed wire to the stick of a kite, and upon elevating it in the air during a thunder-storm, as the string became wetted with rain, it conducted electricity from the clouds, which on its arrival at the ground was regularly discharged with vivid sparks, and sharp reports, and the analogy converted into an identity.

This great philosopher was overcome with emotions of awe, at the wonderful discovery that the Almighty had

vouchsafed him permission to make regarding the nature of the astounding phenomena of the thunder-clouds; and as the whole of his previous life had been devoted to the humble pursuit of science, and in endeavors to cause its principles to "enrich human life with useful arts and inventions," he immediately sought to apply this discovery to the protection of dwellings from the terrific effects of lightning, by elevating upon them metallic rods, in deep connection with the humid earth, and thus to afford ready continuous paths for the natural flash of electric fire.

The conduction of electricity, by metals, unlike that of heat by the same elements, or their alloys, is not progressive, but instantaneous,—of which the most extraordinary discovery of the present day, the "electric telegraph," presents the strongest example;—and thus if the electricity be intensely accumulated, and the metals in sufficiently large rods or wires, they sustain no elevation of temperature, they undergo no chemical change whilst conducting the charge; if, on the other hand, the rods or wires are but small, or insufficient to conduct it with extreme facility, not only do they become sensibly elevated in temperature, but so intensely heated, that they are excited to combine with the oxygen of the air, and actually to burn, as iron filings will do when shaken into the heated air arising from a common flame.

But these filings might have been obtained by filing the bar of a fire-grate, and it does not burn away like them. Why is this? does it chemically differ from them?

No, the difference is merely mechanical; the constituent particles of the bar of iron are strongly bound together into one large and compact solid form; and

although subjected day after day to the burning fuel, the bar conducts away to the adjacent iron and stone-work; the heat as it is excited by the flames, does not admit of its concentration upon any one particular point of its own surface, and therefore never becomes sufficiently heated to attract oxygen and burn, as it will do immediately and chemically, when its attraction of aggregation is mechanically destroyed by the file.

Fig. 46.

So will iron and other metals, when drawn into the slender form of "bell-wires," immediately heat and burn, whilst endeavoring to conduct an intense charge of the electricity of the laboratory, or a flash of lightning from the heavens; but in the stouter form of bars or rods, of an inch in diameter, they will instantly and perfectly conduct both, and sustain no change.

Accordingly, rods of such diameter, either of iron or of copper,—this latter metal being preferable, though most expensive,—are attached to buildings as "good conductors" for preventing the lightning discharging itself and exerting its destructive power upon the bad or imperfect conductors presented by stone, brick, and wood work.

The engraving represents a building furnished with a "lightning conductor," and its construction may be probably understood by the following description.

On the summit of the roof is firmly fixed a metal bar, two inches square at its base, and gradually tapering upwards to a height of twelve feet, terminating in a perfectly sharp point which is strongly gilt, to prevent its corrosion or oxidation by the air and moisture; the base of the bar is made two inches square, that it may not be materially swayed from the perpendicular by the force of storms, and to prevent rain from being attracted by its means amidst the wood work of the roof, which would cause decay; the square bar is provided just above its base with a conical cap of its own metal spreading six inches all around, which thus will cast the rain drops away from the summit of the roof.

Immediately above this conical cap, an iron bar of two inches square, and of any convenient length, is firmly secured to project as an arm horizontally, and to its extremity, by a bolt, is united an iron bar of one inch square, which then proceeds in the same slope as the roof, though supported one foot distant from it by several iron stanchions, until it reaches the eaves, where it is bent, if necessary, to suit the curves, and then proceeds perpendicularly, in a line parallel with the wall, though still kept one foot distant by stanchions until it enters the ground.

As iron will soon rust in damp earth, and as upon the perfect metallic nature and continuity of the bar its utility as a lightning conductor depends, this extremity, as well as the other pointed and gilt, must be preserved unharmed; accordingly a channel about one foot in width,

and of length according to circumstances, is constructed of brick work, extending horizontally beneath the surface of the earth, and in the centre of this channel the iron bar is bent and laid; it is then closely packed around with dry wood-ashes, and when the channel is quite filled, it is bricked over, and a small pent-house formed around the part of the bar that first enters the ashes from above.

Fig. 47.

Upon emerging from this channel, the iron bar is either strongly painted or varnished, then bent into a perpendicular or gently sloping direction according to local circumstances, and carried as far into the damp earth, or, if possible, into a stream of water, as its point extends into the atmosphere; this lower extremity of the bar is generally fashioned into the form of a sharp trident.

The "conductor" is thus completed, and upon the approach of thunder-clouds its point will slowly and silently disarm them of electricity, and conduct it to the earth and water; and thus restore an equilibrium that otherwise might have been suddenly and violently effected by a flash of lightning destroying the building.

Although the "conductor" is supported by iron stanchions projecting from the roof and wall of the building, these will not divert the electricity from the "conductor," for electricity always chooses the direct path that

is proffered, and will not leave it, or fly to lateral conductors.

Ships are protected by "conductors" generally made of copper bars attached to their masts, and carried down in connection with the water; and by these "conductors" much fearful damage by lightning has been prevented.

The chemist, by subjecting a portion of air to the long-continued discharge of electricity, proves that the elements Oxygen and Nitrogen, combine and produce Nitric Acid, which has a very powerful odor and action upon organic matters, as already stated; guided by analogy, he ventures to pronounce that the protracted discharge of lightning through the atmosphere may effect a similar combination of elements, and produce such compound upon a more gigantic scale, and that the peculiar odor which pervades the tumultuous atmosphere of a thunder-storm may be that of Nitric acid; and still guided by analogy and by the perfect examples of Beneficial design that he discovers throughout Nature, he ventures yet farther to state that this production of a powerful acid may be destined to aid the commotion of the storm in destroying and removing the mephitic exhalations that arise from organic matters putrefying in the heat of Summer and of Autumn.

Like every other Natural phenomenon, this of the thunder-storm is evidently productive of good, for when it has passed, the atmosphere directly imparts a sensation of purity and freshness that it did not previously; animal life revives, vegetation sends forth a more powerful aroma, excited probably to exhale more oxygen, and the whole beautiful aspect of the earth seems to rejoice in the recovery of its wonted tranquillity.

The occurrence of thunder-storms is always greatly dreaded by the husbandman, not only on account of the extreme probability of the lightning striking his homestead, and thus instantly kindling its well-stored harvest in one consuming flame, but also on account of the usual concomitants of sudden and violent showers of hail and rain which burst from the clouds, and so lacerate and prostrate the standing crops, so tear the fruits and strip the leaves of orchards, that frequently, after the storm has passed, these fragile structures can scarcely, if at all, recover from the shock to meet the bright rays of the sun, and ripen into the maturity of an autumnal harvest.

The physical cause of these dread concomitants of the thunder-storm, rain and hail, is shrouded in impenetrable mystery; no man can "understand the spreadings of the clouds," no man hath "seen the treasures of the hail," but the terrible visitations of these agents of Divine power have been experienced by mankind from the earliest ages of the world; for it is recorded in the Sacred Writings as follows:—

"The Lord sent thunder and hail, and the fire ran along the ground."

"He maketh lightnings with rain."

"He destroyed their vines with hail."

"He smote with hail in all the labors of harvest."

"The voice of the Lord breaketh the cedars, yea, the Lord breaketh the cedars of Lebanon."

As in the earliest ages, so at the present time, the countries of the East, and especially in the immediate vicinity of Mount Lebanon, which is nine thousand, six hundred feet in altitude, are yet subject to the foregoing tremendous visitations; and even in this country they occasionally occur in a scarcely inferior degree.

Regularly shaped hail-stones and shapeless masses of ice, three, six, and even nine inches in circumference or girt, suddenly shower down from the clouds, and devastate not only the corn-corps and orchards of open plains and valleys, but the exotic flowers and fruits, which are sedulously kept in conservatories, by the refinements of horticulture.

"The time of the continuance of hail is always very short, generally only a few minutes, and very seldom so long as a quarter of an hour; the quantity of ice which falls from the clouds in so short a time is prodigious; the ground being sometimes covered with it to the depth of several inches.

"The clouds, from which hail is precipitated, appear to be of very considerable extent and depth; it has been remarked that they have a peculiar gray or reddish color, and that their lower surfaces present enormous protuberances, whilst their edges exhibit deep and numerous indentations."

Fig. 48.

A mineral, beautifully transparent, colorless, and having the regular form of a six-sided prism, with a six-sided pointed summit, was well known to the ancients, and they imagined it to consist of water more intensely and compactly frozen than common ice, and therefore incapable of thawing by solar-heat—this substance they

termed "Crystal;" the modern chemist discovers it to be the purest form of the earth Silica, and he employs the word "crystal" to denote any solid substance, either native or artificial, that presents itself in a regular figure, however different such figure may be to that of ancient "crystal."

Upon examination of a hailstone received upon a soft yielding surface, and thus prevented from shattering by its violent collision with the hard solid earth, it exhibits the crystaline form of a short six-sided prism, having at each end a short six-sided pyramid, one being invariably "truncated," or cut off, as shown in the annexed engraving.

Fig. 49.

The known phenomena attendant upon the ordinary transition of water to the state of ice will claim our attention hereafter; leaving, therefore, the unknown physical cause of hail and its crystaline form, let us proceed to investigate another phenomenon.

In addition to the various physical forms of rain, dew, mist and hail, in which water most commonly descends upon the earth throughout the seasons of Spring, Summer and Autumn, it sometimes pours down in one gigantic and unbroken liquid column, and then is popularly "the water-spout."

The electrician and the chemist, by observation, experiment and analogy, are led to conclude that, during certain states of the atmosphere, although a cloud may

not be so powerfully charged with electricity as to seek a restoration of its equilibrium by emitting a disruptive flash of lightning to subjacent objects, it may be sufficiently charged when at a moderate elevation, that its own entire and mobile volume of aqueous particles, will yield downward in the form of a watery column, through which the inherent electricity seeks a rapid though silent discharge; the same,—to use a very homely simile for conveying an idea regarding the mere attraction and transit—as a large flock of cotton nearly saturated with water, when held in one hand, may have its filaments drawn out by the other, in an unbroken form through which by capillary attraction the water will pass in a smooth and silent stream, until its excess has thus drained away.

An electrical cloud, when thus yielding to the attractive or inductive power of the objects over which it hovers, is gradually drawn from its rounded form into that of a fringe, and this gradually accumulates into the form of a well-defined point; then as the distance between the cloud and subjacent bodies diminishes, this point becomes more and more elongated, until at length it forms an unbroken conductor, not only for the discharge of the electricity of the clouds, but likewise for a torrent of its waters; and these phenomena having ensued, the cloud is found either to have wholly vanished, or to present but a miniature semblance of its original form.

Generally speaking, the electricity of the "waterspout" is not so much to be dreaded as the vast aqueous torrent, that descends with impetuous force upon the dwellings of man and the labors of the field, which are

all alike overthrown and prostrated, and swept away by by this sudden and concentrated inundation.

The occurrence of this extraordinary natural phenomenon is by no means so common inland as at sea, and there it displays itself in a yet more striking and remarkable form.

There, in place of the solid and fixed earth, the liquid and flowing water presents an attractive surface for the floating and mobile vapor of the electric clouds.

In such case, not only does the electric cloud emit an elongated portion of its volume as a precursor of the full descent, but the level surface of the water simultaneously gives rise to a mobile pointed wave, and thus by mutual attraction, the former continuing to descend and the latter to ascend, they at length suddenly coalesce, and form an aqueous conductor for the restoration of the electrical equilibrium; and having effected this, the waters of the cloud are ultimately received into the bosom of the ocean, from whence they were exalted by the imponderable agency of heat.

An idea of the form of this remarkable, and when minutely considered, important phenomenon, may be gained by reference to the annexed engraving.

A sudden and violent concussion of the atmosphere

Fig. 50.

will frequently cause the descending cloud to burst before its union with the ascending wave, and accordingly mariners are in the habit of discharging a gun in its direction, and of thus averting the probability of the "water-spout" extending and engulfing their richly-freighted and highly-valued ship.

A large, stately, firm structure it may be, in comparison with the hands by which it was fashioned, but it is a small, lowly, and frail shell, in comparison with the incomprehensibly vast and boundless flood of waters upon which it floats; it bears not so great proportion to them as the smallest grain of sand bears to the largest artificial globe; and therefore, instead of considering it as extraordinary that shipwrecks so frequently occur, we should rather feel surprise that they do not more frequently happen, and astonishment that in vessels so minute, mariners have been permitted to circumnavigate the gigantic world.

"They that go down to the sea in ships, that do business in great waters;

"These see the works of the Lord and His wonders in the deep."

Thus, in addition to wonderful phenomena of constant occurrence, as storm, tempest, hurricane and wave, mariners sometimes behold with astonishment and awe, fiery volcanoes suddenly bursting forth from the depths of the ocean; these are attended by lightning, thunder, lava, steam and water-spouts, all of them—so far as man is permitted to discover—being physically caused by the abrupt, violent and extensive changes which matter is commanded to sustain by "the Creator of the heavens and the earth, the sea and all that in them is."

Changes, miraculous and perpetual, pervade through-

out the creation, and yield an inexhaustible store of materials which are continually presented, withdrawn, and again renewed for mental reflection and experimental investigation.

The vital force displayed by vegetation, from the hour of its germination, and throughout all its successive periods of growth towards maturity, in obedience to the immutable laws of its Creator, is a subject well calculated to draw attention from the servant and interpreter of Nature.

In Spring, when a seed is buried in the earth, this medium, on account of the hardness and solidity of its constituent atoms, might be reasonably imagined capable of exerting such rude pressure upon the first germs of vegetable life, as to crush it almost in the very moment of its nascence, but experience teaches us that no such injury is sustained.

When the entire organic structure is once endowed with vitality, its powers become superior to those of inorganic matter; for example, the "radicle" sends forth soft and tender filaments, yet having sufficient strength during their search of liquid nutriment, to penetrate between hard solid stones, and these filaments, in obedience to gravitation, descend beneath the earth to form a firm and steady root.

The "plumula" simultaneously sends forth delicate and fragile folds having a nearly equal though contrary strength during their search of other nutriment from the air, to part asunder and lift before them, the incumbent atoms of their terrestrial prison, and thus to emerge amidst the ethereal treasures of light and heat, under whose combined attraction, the folds burst into full leaves, a perfect plant soon flourishes, and it is destined

in due season to "yield seed after its kind," which in its turn will then present the same miraculous circle of changes.

When natural or artificial obstacles of great size, solidity, or weight, are opposed to the comparatively small, slender, and light structure of plants, attraction of gravitation and attraction of cohesion, both combine to render the former of superior power to the latter; but in such cases, although the organic forces cannot directly penetrate or lift these obstacles, they preserve as closely as possible the direction that they would have pursued, if not opposed, and will recover it at the earliest opportunity.

The endeavor of plants to remove obstacles opposed to the ordinary direction of their growth, and failing of it, then gracefully yielding obedience to them, seem to have been first remarked in the case of a basket covered with a flat, square stone, which was accidentally placed in the centre of a growing "acanthus," the leaves of which being diverted from their original position, assumed a bending beauty of form, as shown in the engraving, and from this it is said originated the elegant Corinthian capital.

Fig. 51.

In pure Corinthian architecture the "acanthus" en-

tirely surrounds with its aspiring leaves the "basket" or "vase" of the capital, as if attempting to raise the flat stone or "abacus" that covers the whole; they then turn down and form themselves in graceful "volutes."

It is occasionally observed that when plants cannot remove solid obstacles, they will actually enclose them within their own structures; thus, nails and stones have been found imbedded in the trunks of trees, and some Indian nations take advantage of this fact, for the construction of their hammers; they split open the supple stem of a creeping plant, then place an oblong piece of heavy stone in the aperture, and bind it fast with the shoot of another plant of the same kind which is in a growing state; by the end of twelve months the stone is firmly interlaced, the stem which bears it is cut away, and thus a rude hammer is obtained.

But returning to the graceful form of the acanthus or other plant when diverted from its original position, it presents more than its mere outward beauty to the votary of experimental science; for example, remove the stone from the top of the basket, and then it will be seen that all the stems and leaves of the plant, which have crept through the wicker-work and have thus grown in the gloom induced by the opacity of the external foliage, are neither vigorous nor verdant like it, but sickly and pale, thus affording another example, in addition to those adduced at page 97, of the modification of vegetable growth and color when deprived of the free access of solar light.

Even one more example of the same kind will be presented, when the languid foliage is carefully freed from its imprisonment, and the basket lifted; it might have been originally placed upon the grass, near the acanthus or other luxuriant plant, and if this were the case, no

grass will be found, but only a circular spot of bare earth, where the basket stood; because it and the stone being ponderous, crushed the tender blades of grass, and, thus injured, and at the same time prevented from the restorative agency of imponderable light, they had no alternative but to die, and mingle the results of their decomposition with the earth for supporting the growth of surrounding portions free from oppression, and permitted access to the light of day.

The darkness intervening between the bottom of the basket and the bare soil, although inimical to the growth of vegetation, is favorable to the life of reptiles and insects; worms, for example, will appear in abundance, and then quickly shrink, and glide beneath the earth; "centipedes" will rapidly crawl and hide amidst the surrounding grass or foliage, to shun the newly-admitted light; both classes of wonderfully formed beings eagerly seeking localities favorable to their organization and habitudes.

If a few of these "centipedes," or "hundred-legged worms" be gently caught upon a leaf and placed in a small card-box from which they cannot escape, this may be taken into a perfectly dark room, and after a few minutes, when the eyes of the experimenter have become accustomed to the gloom, if the insects be disturbed or irritated by touching them with a feather, they will generally emit a phosphorescent light, resembling that of glow-worms.

All the foregoing examinations can be made without difficulty, and they corroborate the fact so frequently named during this inquiry, that things of common occurrence will present scientific information when properly

investigated; let us now direct our attention to the grand and important feature of Autumn.

"Lift up your eyes and look on the fields, for they are white already to harvest."

Beautiful, indeed, is the sight of white fields of corn, with its richly-laden crop gracefully undulating before the autumnal breeze, but "it is infinitely more animating and delightful to see the stately stems fall beneath the regular and measured stroke of the reaper, whose toil is lightened by the thought that abundance is thus poured from the lap of earth into the garners of her children, to support them when the hour of unfruitfulness is nigh."

"It is a subject worthy the consideration of every one to calculate what a vast quantity of nourishment is by the agency of the vital principle in seeds thus annually abstracted from the atmosphere, the waters, and the earth, and reduced to a state fit to minister to the sustenance of men and animals."

"To secure this precious treasure all persons, young and old, engage in the work of the harvest, and let us hope that there are few who can witness the additions made to our stores of provisions without experiencing a feeling of exultation ending in grateful emotions and thankfulness to Him who promised that 'seed-time and harvest should not fail.'"

An extraordinary fact is elicited by the researches of the chemist, that no inorganic substances either naturally found or artificially formed, though containing the elements oxygen, hydrogen, nitrogen, and carbon, are suited for the support of animal life.

To constitute food, these elements must have been subjected to the recondite laws and powers of vitality

either in the vegetable or the animal creation; or, in other words, food must consist of organized matter; all attempts of the chemist to form food by the direct presentation of elements to each other are perfectly futile.

For the due sustenance of human life, in the vigorous exertion of its manifold functions, a judicious and varied admixture of vegetable and animal food, aided by culinary operations, is absolutely indispensable, but to obtain such food the ground must be tilled and cattle must be cherished.

Grain-bearing vegetables, the chief of which are wheat, barley, oats, maize, rye, rice, millet, beans, and peas, have never been discovered in a natural, or as it is commonly called, a "wild state of growth;" they all require cultivation by the labor of man, thus powerfully illustrating the Sacred Truth, that the fallen destiny of man is "to till the ground from whence he was taken, and in the sweat of his face that he shall eat bread."

"Hate not laborious work, neither husbandry, which the Most High hath ordained."

In former times, when the incessant occurrence of civil and foreign wars distracted men from the labors of husbandry, scarcity of food very commonly resulted, and famine overspread the land; but since the sanguinary strifes have in a great measure ceased, men have "beat their swords into ploughshares, and their spears into pruning-hooks," and returned diligently to their toil, guided by the observations, experiments, and analogies of science, and thus rendered capable of reflecting and reasoning upon the phenomena that they behold, and of bringing scientific principles to bear upon the succes-

sion of crops and the nurture of cattle, so that a general scarcity of food is at present unknown.

Supremely blest with "every good and perfect gift" from the bounteous Hand of God, England presents striking examples of the utility of science when judiciously applied for increasing the advantages, comfort, and benefit of man.

At the same time, sad and heart-rending is the stern fact, that in the very midst of "garners full and affording all manner of store," there is not only "complaining in our streets," but the most appalling cases of misery, of frightful destitution, of utter prostration of the corporeal, of partial aberration of the mental faculties, from want of a scanty pittance of food; nay, dreadful above all, cases of lingering death from absolute starvation.

"Blessed is he that considereth the poor: the Lord will deliver him in time of trouble."

"The rich and poor meet together, the Lord is the Maker of them all."

The philanthropist adorns his country with temples of Christian charity and benevolence, as Public Hospitals for the reception and alleviation of suffering humanity; and upon visiting these meritorious works, in manifold cases, the physician can but too surely point out to him that present disease was caused by previous starvation, and that the restorative now required is generous food, rather than the "medicines out of the earth, of which doth the apothecary make a confection," although such may need to be simultaneously prescribed by the physician, for "there is a time when in their hands there is good success."

The exalted science of Medicine enrols amongst its followers many of the best and greatest men of the age,

men of expanded sentiments and pure philanthropic feelings towards their fellow-creatures, be they high or low, rich or poor, men who are constantly bent upon healing the sick, comforting the afflicted, alleviating the vast and terrible complications of human agonies; men who humbly, yet steadfastly following the footsteps of their Divine Master, are constantly "going about and doing good."

"Honor a physician with the honor due unto him, for the uses which ye may have of him; for the Lord hath created him."

The physician proves, that for the proper formation and renewal of the solid and fluid portions of the human body, in which the chemist discovers Nitrogen as a leading element, a due supply of food, containing Nitrogen in the form of flesh, is imperatively demanded; for it is an established scientific truth, that animals fed entirely upon proximate organic principles not containing nitrogen, invariably sink under such diet, and if its use be prolonged, they will ultimately die, with all the symptoms which are attendant upon death from total starvation.

Although nitrogen is abundantly present in the atmosphere, the chemist discovers that it is never withdrawn from thence or elaborated into the animal body, and that it is always indirectly derived from the organic food taken as sustenance.

Blest with health and strength, happy indeed is the man that "goeth forth unto his work and to his labor until the evening," and can thus obtain a moderate share of both varieties of necessary food, that will enable him to keep aloof from those who would fain persuade him that "raw vegetables and pure water are conducive to

health and longevity;" or who, during his poverty, would penuriously dole out a minimum of animal food, for the miserable support of the frail earthy tenement of his immortal soul, which at length escaping from temporal wrong and oppression, seeks for everlasting mercy and repose in the bosom of its God.

The chemical phenomena attendant upon the nutrition of the human body by a proper supply of food, are but little known, and vain is the attempt to bring ordinary laboratory processes forward in aid of such recondite functions of vitality.

The human body, whilst endowed with vitality, exerts an action upon every variety of food that defies imitation by the utmost stretch of chemical skill; but it is discovered that food undergoes a remarkable change after mastication and mixture with the secretions of the salivary glands, and transposition by deglutition into the stomach.

A secretion of the stomach called "gastric juice," exerts a powerful solvent agency upon the food, and during digestion reduces it to a semifluid white matter called "chyme."

The gastric juice is a most energetic solvent of every kind of food, which of a necessity must be matter deprived of life; but it has no action upon the stomach in which it is secreted through the mysterious agency of vitality; and that vitality is the sole cause of the suspension of the solvent power of the gastric juice, becomes evident after death, for then the stomach, like food, is often found to be corroded and dissolved.

Chemical analysis of the gastric juice does not materially enlighten experimenters regarding its solvent powers, but it contains a peculiar acid, termed the hy-

drochloric, probably derived from common salt, naturally contained in the generality of food and drink, or added to it as a condiment. The small quantity of hydrochloric acid, and of other acids and peculiar principles supposed to exist, are insufficient to account for its power upon food, and it must be referred to the recondite agency of vitality.

"Chyme," the first product of digestion, may be considered as intermediate with the original food and arterial blood; from the stomach, this chyme proceeds into the small intestines, and meets with another extraordinary secretion termed "bile," which mingles with it, and very probably confers some alkaline matter; a chemical change is likewise sustained by the chyme, in consequence of its contact with the bile, for it separates into two portions, one of which passes into the large intestines, and is ultimately voided as excrementitious; the other a milk-white fluid termed "chyle," which is rapidly absorbed by a peculiar set of vessels termed the "lacteals," and by them transmitted to the thoracic duct, and from it to the venous system.

Upon entering the venous system, the whiteness of chyle is succeeded by a dark purple color, referable, as it would appear, to the absorption of a superabundance of Carbon, which would prove hurtful if retained in the system.

The Creator has ordained that this purple or venous blood is to be received by the right cavity of the heart, which wondrous organ, by regular pulsations, transmits it to the lungs, where, extremely diffused by their peculiar membranous structure, it is exposed to the influence of the air, and the changes immediately ensue, as already mentioned at page 69.

The blood, thus deprived of its excess of carbon, returns to the left cavity of the heart, as red arterial, or perfect blood, containing a peculiar coloring principle, termed "hæmatosin," and the two other proximate principles already mentioned as fibrin and albumen; a small proportion of saline matters; and it is endowed with the power of circulating throughout the system, for the secretion of new parts, and for the removal of such as have performed their functions. Whilst circulating throughout the system, the blood is a homogeneous fluid, but upon removal it spontaneously separates into a solid and a fluid portion, the former containing the coloring principle, and fibrin, the latter, the albumen.

The human mind has always a tendency to seek into incomprehensible matters; but incessant and laborious as have been the researches regarding the physical cause of the functions of digestion, nutrition, respiration, and animal heat, very little of real importance has been discovered beyond the above statement; "though a wise man think to know it, yet shall he be not able to find it."

Of all the varied productions of Autumn, the corn harvest is of the utmost importance to mankind, and therefore a few general observations upon the chemical nature of the proximate principles contained in wheat, and to which the nutritive property of good bread may be referred, will claim our attention at this period of our inquiry.

In "harvest work," the utmost care is taken that the sheaves of corn are perfectly dried by the combined influence of the sun and air, before they are carted from the fields, and housed in barns or stacked in rick-yards; care is likewise taken to cleanse them as much as possible from tares, thistles, and other succulent plants,

which are ordained to accompany the growth of wheat; because, like hay, all varieties of corn, even when pure, will heat, if stacked whilst damp, and with even greater facility, if contaminated by succulent weeds; whereas if dry, there is no danger of its becoming heated and musty, and unfit for food.

The methods of thrashing, winnowing, and grinding the grains of wheat into flour, are too well known to require comment; but if we turn our attention to the flour, we shall discover a few facts that are not so generally known.

Knead a portion of flour with water into the size and shape of a dumpling; then hold it beneath a slender stream of water, and continue to knead; at first the water will flow away perfectly milk-white, and this may be received in a pail, and set aside; then the water will gradually become less and less white, until at length it flows unchanged, and leaves upon the hands a gray, tough, elastic substance, very much like bird-lime; it is called Gluten; it is a proximate principle, which existed in the flour, and is educed by this first or simple analysis.

Gluten, when submitted to ultimate analysis, by an experienced chemist, yields the ultimate elements, Carbon, Hydrogen, Oxygen, and Nitrogen, as at page 34; and on account of containing the last-named element in considerable abundance, and therefore being nearly identical with the Fibrin and Albumen of the animal body, Gluten is frequently called a vegeto-animal principle, for it gives to articles of diet in which it exists, a nutritive power nearly equal to that of animal food.

Wheat flour contains more gluten than that of any other grain, and hence the superiority of wheaten bread

over barley bread, or rye and oaten bread; it is lighter and more digestible.

The chemist discovers that the warmth of the season materially affects the formation of gluten in wheat, that it is most abundantly found in the wheat of southern climates; and hence this is peculiarly excellent for the manufacture of vermicelli and macaroni, which are very nutritious articles of diet.

If gluten be perfectly dried, by long exposure to steam-heat, it will undergo no change by keeping; but when moist, it will rapidly enter into putrefaction, and exhale the same offensive odor as putrefying flesh, and for the same reason, because it contains Nitrogen, and this combining with Hydrogen, forms the volatile substance called *Ammonia*.

Upon examination of the milk-white water that ran from the ball of dough, when kneaded, to obtain gluten, it will not be found so white as it was, and by gently inclining the pail on one side, to pour it away slowly, a white sediment or precipitate will be found at the bottom; this is another proximate principle of wheat flour, called Starch; and when correctly analyzed, it is found to consist of Carbon, Oxygen, and Hydrogen only, as at page 34, and to present no trace of Nitrogen.

Starch, when moist, soon becomes acid, from the production of vinegar; but when dried, it may be kept for years without undergoing change; it is insoluble in cold water, and only mingles with it mechanically, so that by repose it quickly falls to the bottom of the vessel in which the mixture is made; if boiling water be poured upon a paste of starch, then it dissolves and forms a solution more or less gelatinous, according to the quantity of starch that is present; and this solution, when

cold, if added to one of the element Iodine, in water, will immediately produce a deep blue color, which is esteemed by the chemist as an exceedingly marked characteristic of starch.

If a portion of this blue compound, or as it may be called, "iodide of starch," be thrown into boiling water, the blue color instantly disappears, and very seldom returns when the water cools; hence the experienced chemist, when testing for starch by iodine, or *vice versâ*, always takes the precaution of employing the solutions cold, or he will fail in obtaining the blue color, even though abundance of both substances may be present.

Pure starch is perfectly white, but is apt to assume more or less of a yellow tinge in the course of time; hence the manufacturer of this proximate principle for domestic use, confers upon it a slightly blue tint, by the addition of a small quantity of "smalt," or "oxide of cobalt;" this renders it perfectly unfit for all refined chemical purposes, and for such the pure white starch of wheaten flour, or of arrow-root, must be invariably used.

An aqueous solution of iodine is easily made, by placing one grain by weight of such solid element in a pint bottle filled with rain-water, and leaving it for a few hours; if, then, a portion of this solution, which has the color of brown sherry, be poured into another and smaller bottle, and a few grains of wheat or barley thrown into it, even upon agitation for several minutes no blue color will be produced, and yet we are certain that the respective grains must contain starch; then why does the iodine fail in immediately detecting its presence?

For a reason that often presents itself to the chemist during his manifold experiments upon organic and in-

organic matter, and that has more than once been presented during our rapid and general inquiry; viz., that mechanical structure or attraction of aggregation opposes chemical attraction or affinity, and in the case now presented it is that of the thin hard coating of bran or husk around the grains which prevents the contact of their starch with the iodine.

Place the mixture of iodine and grains of wheat or barley in a mortar, and crush them with the pestle thus mechanically destroying their attraction of aggregation,—that of the solid iodine being already destroyed by chemical solution,—and then, the starch that they contain will meet with the iodine, the two substances will combine, and produce the blue color, or iodine of starch.

Again, if perfectly dry iodine, and perfectly dry starch, be rubbed in a mortar, no blue color will appear, because neither of the substances is sufficiently divided by this mechanical proceeding to exert chemical attraction; but the addition of a few drops of water will effect a chemical division, or a solution of part of the iodine, and then it will immediately and chemically combine with the mechanically divided starch; it is also probable that a slight solution of the starch simultaneously takes place.

Like as with "soda-water powders," consisting of dry tartaric acid and carbonate of soda, though both are mechanically divided, they exert no chemical action upon each other; but when thrown into water, they are simultaneously and chemically dissolved, and in such state of solution far exceeding in attenuation the utmost exertion of mechanical communication; they are immediately brought into perfect and mutual contact, and then display their chemical incompatibility; "as

vinegar upon nitre," (natron,) by evolving a form of carbonic acid.

Bread contains gluten and starch; the latter may be detected by a very simple experiment:—place a thin slice of bread on a plate, and moisten it with an aqueous solution of iodine; and from being white or nearly so, it will become dark blue, because in bread, the starch, though still solid, is neither dry, nor protected as it was in the grain.

If the blue-stained bread be now placed on another plate, and covered with a solution of "ammonia" or strong "hartshorn," the blue color will vanish, in consequence of a very extraordinary affinity that some of the elements of the ammonia have for the iodine, which is greater than its affinity for the starch; or, in other words, in the one case a compound is produced, and in the next it is decomposed.

Starch may be decomposed by the mere application of a moderate heat, as in baking or roasting; it then becomes brown, and soluble in cold water, and yields no blue color with iodine; in fact, the heat has disturbed the original arrangement of its proximate elements, Carbon, Hydrogen, and Oxygen, and caused them to group together as Gum; reference is made to its composition at page 34.

A piece of bread is insoluble in water, and therefore confers no taste; if a piece of bread be toasted brown, and then thrown into water, it forms the beverage well known as "toast and water," which has a mucilaginous taste, and for this reason, the heat of the fire has converted a portion of the original starch of the bread into Gum; this dissolves in the water, and forms mucilage.

At the same time, during the toasting of the bread, a

portion of its original gluten, starch, and recently-formed gum, are decomposed into volatile matters, which cause the smoking, and peculiar smell of the toast—after the first dampness or steam of the bread has passed away,—but a portion of carbon does not volatilize; it remains, forming the "charred" or "burnt-toast;" and this, when thrown into water, forms a dark brown extract, which colors "the water."

If the bread be more perfectly toasted, so as to become very much blackened and burnt, the resulting charcoal is not useless, as might be supposed; for, upon throwing it into a portion of water unfitted for beverage by long keeping, the charcoal will deprive it of all offensive odor and taste, and render it palatable, yet the theory of this fact is not understood.

By the long-continued action of diluted sulphuric acid upon starch, the chemist can further derange the natural proportions of its elements, and produce Sugar, a proximate principle likewise consisting of Carbon, Hydrogen, and Oxygen, as shown at page 34.

A small proportion of Sugar exists in wheaten flour, and likewise another principle called Albumen; but these require a very considerable amount of chemical knowledge for their eduction, and the details of the process would encroach too much upon the prescribed limits of this examination; reference, however, must be made to the fact, that wheat flour, in addition to its organic principles, gluten, starch, sugar, and albumen, contains notable traces of the inorganic compounds, called phosphate of lime and phosphate of magnesia; and it is a most remarkable fact, that these inorganic substances are transferred from wheaten and other food

in which they exist, into the constitution of the bones of man, and of the higher order of animals.

The extreme utility of manuring wheat lands with recent "bone-dust," consists in the fact, that the organic, or tough matter of the bone called Albumen, is extremely prone to putrefy, and thus render soluble the phosphates of lime and magnesia, with which it is associated; these are accordingly rendered into a state suitable for absorption by the rootlets of the growing grain, and are chiefly transferred to the ear, whilst the silica and potash are arrested, to form the glistening straw, as mentioned at page 143.

Bones, when calcined or burnt, have all their really organic matters, such as albumen, fat, and oil, destroyed and dissipated, and nothing but their inorganic phosphates remains; such "bone-ash," although invaluable to the chemist as a source of phosphorus, is not so to the agriculturist, because it is insoluble, and not easily or perfectly received by the rootlets of plants, and therefore it requires solution, or rather decomposition, by the agency of diluted sulphuric acid, before it is added to the soil.

Bone-ash is the source from whence the chemist elicits all his supplies of phosphorus,—about twenty thousand pounds weight per annum,—for the manufacture of "Lucifer matches," he generally effects the decomposition of the bone-ash by submitting it to the action of charcoal and sand at a red heat; these agents deprive the phosphoric acid of oxygen, and elicit phosphorus, as the "red lead" deprived hydrochloric acid of hydrogen, and elicited chlorine, at page 218.

Another most important office of the organic matter of bone, and of animal and vegetable manures in which

nitrogen exists as an ultimate element, is to supply this extraordinary form of matter to growing plants; hence it is found that wheat, grown upon soils chiefly manured with nitrogenous matters, contains a relatively large proportion of gluten; and the same remark is applicable to the growth of other vegetables, for it does not appear that any of them have the power of secreting nitrogen directly from the air; it enters their living structure indirectly from the decomposition of dead organic matter, and when the season of maturity is attained, such vegetables become the food of animals; nitrogen enters into the composition of their flesh, and this, conjoined with the use of vegetables as food, aided by proper culinary operations, then enters into the constitution of the human body; at least so it is presumed, according to the observations and experiments of the ablest physiologists and chemists.

The use of quick-lime as a manure is on account of its causticity, soon rendering dead organic matters soluble, and fit for the nutrition of growing vegetables; and having performed this office, it gradually absorbs carbonic acid from the atmosphere, reverts to the state of neutral carbonate of lime, and then sustains the office of absorbing the water of the shower, or the aqueous vapor of the air, by capillary attraction, and thus preserves a reservoir of nutriment for the plants that it supports.

The offal of the stable and fold-yard is invaluable as manure, because it returns to the soil a very large proportion of the proximate and ultimate elements, that were taken from it by the growth of the hay and corn-crops; it returns them in a state fitted for affording vegetation the support that it demands; these facts regarding manures are not of such recent date as some persons imagine;

they are to be found in the works of the chemist who first devoted his unrivaled talents to agriculture upwards of thirty years ago, and to whom the agriculturist is deeply indebted for the rational principles upon which he now successfully conducts his labors.

Very few vegetables are destitute of Gum; it contributes to their nutritive powers, and when pure, is wholly soluble in cold or hot water, forming a mucilage; it frequently exudes spontaneously from the stems and barks of trees, as from the plum, cherry, apricot, and almond; but the substance most popularly known as a gum, is the produce of the "acacia vera," a plant that is very abundant in Morocco.

As gum exists in vegetables, it appears to have some nutritive properties, and it is said that during the gum harvest the Arabs subsist principally upon it; and moreover, that a large caravan of Abyssinians would have starved, had they not fortunately discovered among their merchandize a large stock of gum, upon which one thousand persons subsisted for two months.

The sweet and luscious taste of fruits may be chiefly, if not exclusively, referred to the presence of the proximate principle well known as Sugar, and it is possessed of considerable nutritive powers; it is soluble in hot and cold water, forming a syrup, which, if concentrated, will yield four and six sided prismatic crystals as seen in sugar-candy, and thus materially differs in its physical state from gluten, starch, and gum, which are uncrystalizable.

The composition of all the proximate principles that have been considered, including sugar, will be evident upon reference to page 34; the source of the enormous supplies of sugar, is well known to be the "sugar cane,"

or "arundo saccharifera," and therefore demands no detailed mention here; the annual consumption of sugar furnished from this plant, and the vast amount of carbon that it contains, are shown at page 88.

Sulphuric acid has a strong attraction for water, and in combining with it as at page 220, a great elevation of temperature results; but the chemist discovers that the acid has no attraction for carbon; now analysis teaches him, that all the proximate principles of which mention has been made, consist of the elements of water, viz., oxygen and hydrogen combined with carbon.

He therefore reasons as follows:—if sulphuric acid be presented to such proximate principles of vegetables, say to sugar for example, it might probably combine suddenly with the oxygen and hydrogen or water, and liberate or educe the carbon; he tries the experiment and discovers the truth of his supposition.

Place a quarter of an ounce of powdered sugar in a small gallipot, and add sufficient sulphuric acid to moisten it perfectly, stirring the two substances together with a piece of stick; this will appear as if charred, and it really is so, by the sulphuric acid decomposing it first in preference to the sugar, which will then change into a gum-like mass, and afterwards blacken by the evolution of its carbon.

Or, the experiment may be rendered more striking by moistening another portion of sugar with a few drops of water and then adding the acid, stirring as before; this purposely added water will combine so energetically with the acid, as to induce the oxygen and hydrogen, or actual water of the sugar, to accompany its combination, and the sugar thus decomposed will yield a large mass of carbon.

The stick should be about one foot long, and the gallipot set upon an earthenware plate, lest it break by the heat of the action; and the operator must not hold his face directly above the arrangement, for sometimes portions of the materials are thrown from the vessel and might do serious injury.

Sugar has been frequently obtained from the "sugar-maple" or the "acer saccharinum," also from the "beet-root" or "beta vulgaris," and it may be extracted from many vegetables and fruits that have a sweet taste, but it does not uniformly assume the crystaline, form; thus, for example, "grape sugar" is not crystaline, neither is "honey sugar;" accordingly such varieties of saccharine matter are called "granular sugars."

A solution of absolutely pure sugar in water will undergo no change by keeping for a great length of time, but recently expressed saccharine juice, that of the sugar-cane, for example, will rapidly become acid; this is owing to a curious and complicated change that is induced by extraneous matters, which are simultaneously present in the juice, and therefore the "sugar-boilers" evaporate it as rapidly as possible to obtain a large product of sugar before it spontaneously changes.

Sugar must be present in all cases of vinous fermentation, a process which appears to consist in a portion of the carbon and oxygen of the sugar escaping as carbonic acid, whilst the remainder and the whole of the original hydrogen combine to form alcohol.

In the case of vegetable matters not containing sufficient sugar, its formation is induced in them artificially by partial germination; thus, barley is converted into malt, or in other words its original starch transmuted

into sugar, as that of the "cotyledons" of the bean was changed during germination.

The process of malting consists in moistening barley with water, heaping it up, and thus inducing germination to a certain extent; that is, to let the seed grow or vegetate up to that point at which it contains its maximum of sugar: if allowed to continue growing, the sugar at first formed is afterwards consumed by the young plant, so that, at the proper period, vegetation is checked or destroyed by the heat of a kiln, and then the barley is said to be "malted;" it has an exceedingly sweet taste.

The juice of the grape, when first obtained in the "wine-press," is technically called "must," and it will spontaneously ferment, because grape juice contains a peculiar form of "gluten," which extraordinary substance induces this change and production of alcohol in wine.

An infusion of malt, or "sweet-wort," on the other hand, does not contain this peculiar gluten, and accordingly a portion of ferment containing nitrogen in the form of "yeast," must be added to induce fermentation and the production of alcohol in malt liquor.

The froth or scum that is so well known to arise upon the surface of fermenting liquors, consists of carbonic acid gas; hence the danger of entering a room in which the process is going on, because its atmosphere becomes contaminated with the mephitic vapor, which is as eminently fatal to life as the carbonic acid produced by the direct combustion of charcoal in air.

If a few lighted shavings be thrown into the carbonic acid arising from fermenting liquor, they will be instantly extinguished, as effectually as though they

were plunged into the liquor itself: this curious fact at first only afforded amusement to the philosopher, but he was soon induced to examine it more particularly, and this led him to a general investigation of all kinds of air; in fact, to the foundation of "Pneumatic Chemistry," and he crowned all his labors by the discovery of Oxygen.

Carbonic acid when cold is much heavier than air, and therefore, if undisturbed by currents or draughts, it will remain as a distinct stratum on the floor of the room in which fermentation is proceeding, and not generally diffuse itself through the whole of the air as it does when ascending hot from a charcoal fire; accordingly, a person might stand near a fermenting-vat without experiencing giddiness or faintness, the lower part of the body alone being immersed in the stratum of cold carbonic acid; but should he stoop to lift anything from the floor, he would be instantly stupefied or suffocated by this mephitic exhalation.

Many fatal accidents have happened from forgetfulness or inattention to these facts, more particularly in large breweries, where, after the liquor has been run off from the vats, men attempt to descend for the purpose of cleansing them, and suddenly encounter the invisible yet deadly vapor that still remains.

The precaution of letting down a lighted candle should never be omitted; if its flame burn as usual, the atmosphere of the vat is safe; if it become dim, there is hazard; if it be extinct, there is certain death awaiting the first person who descends.

It is a well-known fact, that fermentation never ensues in the grape itself, which if left on the vine, or

even after being gathered, shrinks and dries up into raisins, without showing the slightest vinous tendency; and the cause of this appears to be, that the husk or membrane of the grape is so peculiarly formed as to allow of the transpiration of water from the pulp, but to arrest the entrance of air or oxygen from without.

Grapes have been pressed in the vacuum of an air-pump, and the resulting "must" showed no tendency to ferment, but did so instantly upon the admission of the air; hence, a bunch of grapes will become dry raisins if left uninjured, but will yield alcohol, when their membranes are broken to admit the access of oxygen to the gluten they contain.

The chief bulk of vegetables consists of a principle called Lignin, or woody-fibre, and the diversity of forms in which they present it to the attention of the chemist, calls forth his wonder and admiration.

In a dense and compact state, lignin constitutes forest timber; this is felled in Autumn, and allowed to dry or season; we then employ it in the construction of our dwellings, its extreme permanence fitting it admirably for such purpose, whilst its perfect insolubility in water, and its buoyancy upon that liquid enables us to build ships, and thus to explore the wonders of climates far distant from our own.

But all kinds of wood are not equally adapted for the latter purpose; ebony and "lignum vitæ" are heavier than water, and will immediately sink through it as stones, whilst oak and pine are lighter, and will float with great buoyancy; the actual proximate principle, lignin, is of the same density in these heavy and light woods, but in the first it is closely compacted, as the water of a hail-stone, whilst in the latter it is loosely aggregated as the

water of a snow-flake, and involves amongst its pores a considerable volume of air.

If the air be removed from a lump of oak or pine, these will no longer remain buoyant but will sink through water like ebony or "lignum vitæ;" very simple experiments will prove this fact: for example, boil a piece of oak in water day after day until the air is expelled from its pores, and then it will sink; or tie a lump of lead to a piece of pine that it may sink in a tall glass filled with water; place this beneath the receiver of the air-pump, and proceed to exhaust: as this is done, myriads of air-globules will escape from all parts of the wood and emerge at the surface of the water; maintain the vacuum until these cease, then admit the air, which will press water into the pores from whence the air-globules escaped; or in other words, will saturate the reticulated or net-work structure of the wood; and now, upon detaching it from the lead, it will sink with nearly the same facility as that metal when thrown into water.

During the agonies and struggles of a harpooned whale, the gigantic creature has been known to draw a boat entangled by the harpoon line, to such an extreme depth of the ocean, that the pressure of the water forced the air from the wooden planks, and assumed its place, so that the boat, when ultimately recovered by the whalers, was no longer capable of floating, and in fact was worthless even for the purpose of fuel.

In varying forms of compactness and strength, lignin constitutes a chief part of inferior plants, such as hemp and flax for example; these admit of being wrought by handicraft into cordage, canvas, and linen, and when these fabrics are no longer applicable to their original

uses, they may be converted into paper of inestimable value.

Delicately elaborated by the Hand of the Creator, this curious proximate principle lignin, constitutes the network or skeleton for the reception of the pulp and juices of fruits; it contributes to their form, and its elements, namely, carbon, oxygen, and hydrogen, slowly yet certainly relinquish their original affinities, and assume those required to produce saccharine matter, during the progress of ripening, under the agency of Light and Heat. The chemist obtains absolutely pure lignin from wood, by removing all soluble matters with water, acids, or other solvents, and then he finds it to consist only of the three elements above named, and to be totally dissipated in the form of carbonic acid and water during the act of combustion.

But in wood, lignin is associated with portions of earthy, saline, and alkaline matters, which the tree, during its vitality, secreted from the soil; and accordingly, when wood is kindled, its pure lignin changes into carbonic acid and water, whilst the earthy, saline, and alkaline matters being incombustible, remain as white ashes, which under ordinary circumstances are generally very light and easily scattered by the wind; hence the expression in Holy Writ,—"He scattereth the hoar-frost like ashes,"—has reference to the whiteness and lightness of the ashes of wood, which was the chief fuel employed in early ages.

Upon accurate examination of wood-ashes, the chemist discovers them to contain the compound already spoken of as pearl-ash or carbonate of potash; not that it actually existed as such in the wood, but there more

probably as acetate of potash, the acetic acid changing into carbonic acid by the action of the fire.

During the clearing of vast forest tracts, the fallen timber is regarded as an incumbrance rather than of value; and in order to remove it, enormous piles are arranged and kindled, the lignin and other organic matters are dissipated in flame and smoke, chiefly producing carbonic acid and the vapor of water, whilst the inorganic matters remain as fixed ashes.

These, when purified by solution in water, filtration, and evaporation, afford carbonate of potash very nearly pure, and are technically called "Pearl-ashes;" the chemist, knowing that lime has a strong attraction for carbonic acid, adds lime to carbonate of potash, and thus forms insoluble carbonate of lime, as at page 71, whilst potash or oxide of potassium remains in solution, and then, by evaporating the water, solid potash remains, which, if heated with iron under certain conditions, gives oxygen to the iron and forms oxide or rust of iron, whilst the potassium is emancipated in its elementary or metallic form, though capable of floating upon water and burning into oxide of potassium or potash, by decomposing the water and combining with its oxygen, of which hereafter.

The uses of carbonate of potash, as immediately found in the white ashes, or of the potash obtained by the agency of lime, are most numerous; both are employed in the arts of dying and bleaching, and also in the manufacture of glass; for oxide of potassium, or potash, as it is more commonly called, (from the circumstance of the combustion of wood for its production being originally conducted in iron pots,) is discovered to have the power of uniting with oxide of silicium or silica, and

many other metallic oxides, to constitute glass, either pellucid and colorless, as rock crystal, or tinted with colors as vivid and varied as those which court our admiration and wonder in the amethyst, topaz, ruby, sapphire, and emerald.

By the employment of pellucid glass, compounded of the oxides of potassium, silicium and lead, in the form of lenses of enormous magnifying power, man has been enabled to construct instruments for penetrating into space, to watch the career of the heavenly bodies; "the sun that rules by day, the moon that rules by night, and the stars also;" to explain the change of seasons, to predict the return of comets, and gain knowledge regarding the surpassing grandeur and Omnipotence of the God who created, and still upholds the boundless Universe.

Such are a few of the extraordinary phenomena which are presented upon an examination of wood-ashes, but there are two more facts that may be mentioned; in Autumn more particularly, harvest-men kindle a pile of sticks upon the ground to make a fire for cooking their food; and if we examine the circle of embers and ashes next morning, we find them more damp than the soil around; this is contrary to what we might expect: so if we hold a dry glass over the flame of a candle it becomes damp, and this is contrary to what we might expect. What is the reason of these facts?

Why, the burning of the wood has produced pearl-ash, and this is deliquescent, as stated at page 136; and although the circle of the soil became heated, yet during the night it cooled, and the embers and the ashes attracted sufficient watery vapor from the air to dissolve

partially; they accordingly present an example of deliquescence from aërial moisture.

If we collect them and throw them into "hard water," that is perfectly unfit for washing, as it curdles the soap on account of containing a portion of gypsum or sulphate of lime in solution, we shall find, after the lapse of half an hour, that the water has become "soft," even softer than rain-water, that was directed at page 57, to be collected before it touched the ground, in order that it might not dissolve any calcareous or other matter, but remain as water nearly chemically pure; but what is the reason that the ashes of the harvest-men's fire have thus softened the hard water?

Because the carbonic acid of the carbonate of potash has combined with the lime of the sulphate of lime, to form insoluble carbonate of lime or chalk, whilst the sulphuric acid has combined with the potash, to form soluble sulphate of potash, which, remaining in solution, with a considerable excess of carbonate of potash, the latter, instead of curdling the soap and depriving it of oily matter as gypsum would do, renders it all as soluble as it would be if pure or rain-water.

The practical application of this fact is well known in rural districts, and weeds are burned to obtain the ashes; the "wormwood" particularly affords them abundantly, and hence its purified ashes are often called "salt of wormwood."

The reason that the glass does not remain dry when held over the flame as we might expect that it would, is because the hydrogen of the wax, tallow, oil, or gas, combines with the oxygen of the air to produce the vapor of water which the glass condenses, whilst the carbon of such sources of light combines with another

portion of oxygen to form carbonic acid which the glass cannot condense, but it may be detected by lime water, as directed in the experiment at page 71.

One more application of the wood-ashes may be noticed: they have the power of preserving iron from oxidation or rusting, and hence are employed for protecting the part of the lightning-conductor that is carried beneath the soil; and although the carbonate of potash may become perfectly damp, or even dissolved, yet it will still prevent the rusting of iron or steel. The reason of this is unknown to the chemist, but the fact can be appreciated by all.

In addition to the numerous mechanical uses of wood, and its chemical use as a source of artificial heat, the chemist discovers that it is capable of a most curious change or transmutation into edible matter, in fact that a kind of bread may be made from wood.

This is effected by selecting the saw-dust of the least resinous wood, that of beech, for example, washing it with water to remove all soluble matters, and then gently drying it in an oven; after this it is mixed with marshmallow juice and formed into cakes, which are baked at a high temperature; and these reduced to fine powder with the addition of a little corn flour and leaven, form a dough which, when moulded into loaves and baked, constitutes bread more palatable than the bread prepared in times of scarcity from bran and husks of corn.

It is further discovered that absolutely pure lignin, when heated to redness out of the access of air, so that it cannot enter into combustion, is nevertheless decomposed, and that its gaseous elements newly arrange themselves with a part of the carbon, to constitute the

same acid as that resulting from the spontaneous souring of fermented liquors.

The same thing happens when ordinary wood is similarly treated, and thus an abundant store of acetic acid or vinegar is obtained, which is of great value as an antiseptic; and the excess of carbon that remains is of equal importance as a fuel.

Carbon, or charcoal, as it is more commonly called, appears as a black porous solid; and an accurate examination of its habitudes and powers of combination, with other elements, leads to the extraordinary conclusion, that the carbon or charcoal obtained from wood, is identical in its elementary habitudes with the highly-valued diamond.

The properties of charcoal obtained from wood are numerous and important; it undergoes no change by the most protracted exposure to air and water; and hence engineers and architects submit those parts of timbers that are employed as foundations for works in damp soils, or in the beds of rivers, to the preliminary operation of charring.

Charcoal, likewise, exerts antiseptic power over animal food; and although inferior in this respect to common salt, nitre, and vinegar, is yet susceptible of much practical utility; it has also the property of discharging many colors of organic matters, and therefore it is employed for whitening sugar, and other crystaline products of vegetation.

The utility of charcoal as a fuel is very great, more especially in many processes of metallurgy; for in consequence of its powerful affinity for oxygen at an elevated temperature, it not only combines with that element from the air, but likewise with the oxygen present in

the ore; and the ore thus deoxidated, relinquishes its pure metal; a process which has received the name of "reduction."

"If thine enemy hunger, feed him; if he thirst, give him drink; for in so doing thou shalt heap coals of fire upon his head."

This passage is a beautiful metaphor, taken from the ancient practice of smelting ores; and meaning, not to consume the enemy, (for that would be contrary to the precepts of Christian charity,) but to soften and subdue him as the fire melts and reduces metals.

Upon tracing lignin as a chief constituent of the bark of trees, the chemist discovers another example of the power and goodness of the Creator.

Lignin is an exceedingly bad conductor, and therefore only very slowly permeable by heat or cold; thus the covering of bark prevents the sap of trees from disturbance in its circulation by sudden changes in the temperature of the air, and secures it the degree most congenial to the performance of its vital functions.

If the bark were not thus created of bad conducting material, trees and plants would suffer from the heat of Summer, and the cold of Winter; but more especially from the latter, as it would cause their death by the freezing of the sap, a phenomenon sometimes observed during a protracted and rigorous winter; but it can be prevented in many instances by enveloping the trunks of trees with a thicker coating of woody fibre, in the form of matting, or bands of hay and straw.

When tropical plants are transported to cold climates, we artificially clothe them with similar materials to prevent them from suffering by the sudden transition, the same as we should endeavor to protect ourselves, by

putting on an extra garment upon passing from hot to cold weather.

By keeping a thermometer plunged in a hole bored in a sound tree during hot weather, it constantly indicated a temperature several degrees below that of the atmosphere ; and during cold weather a temperature several degrees above that of the atmosphere : and another wonderful fact was also discovered, namely, that sap drawn from the tree would freeze at the same temperature as pure water, whilst the sap circulating in the tree, under vital agency, would not freeze until reduced seventeen degrees below the freezing point of water. This point or degree will claim our attention when considering the leading chemical phenomena of Winter.

It is a generally received and probably correct statement, that heat is evolved during germination,—heat quite independent of that which is popularly known to be evolved during putrefactive fermentation, as that of damp hay, damp corn, or organic manures ;—the temperature of plants is very frequently materially above that of the atmosphere, " and all have undoubtedly a power dependent upon vitality of maintaining to a great extent an equable temperature."

In Summer and Autumn the dense foliage of trees, by its extraordinary non-conducting power, forms the cool shade which at noon-day is so eagerly sought by man and animals from the piercing rays of the sun, and more particularly in oriental climates.

The chemist discovers that the leaves of some very succulent plants will absorb oxygen in the dark, and again evolve it in the light ; some kinds of the " cactus," for example, will absorb more than their own bulk of oxygen, and retain it so tenaciously, that they will not

yield it by the action of heat, nor in the vacuum of an air-pump, but immediately do so upon exposure to the imponderable agency of solar light.

No satisfactory evidence can be adduced regarding the physical cause of the circulation of the sap in plants, nor even of the general direction of its course; but the most accurate researches which have been made upon this recondite subject, render it probable that the chief ascent of the sap from the roots to the leaves, is in the vascular system of the "alburnum," and outer layers of wood; and that having performed its functions in the leaves, as shown at page 84, it chiefly descends by the "liber," or inner layer of bark, giving rise to the formation of new wood, and to the separation of gum, resin, and other proximate principles.

As regards the influence of flowers upon the atmosphere, it appears that they deteriorate it to some extent, and particularly during the night; but it is highly probable that much of the oppression which persons frequently experience after remaining in a conservatory, or room filled with flowers, is in the first place referable to the confined atmosphere being loaded with carbonic acid arising from the tan and soil; and in the next from the concentrated aroma of the flowers, and not from any material deterioration of air by their agency.

Some persons are more affected by the aroma of flowers than others; thus a single hyacinth in a large room certainly cannot deteriorate the air in any appreciable degree, and yet its odor may be extremely oppressive, producing even headache and faintness.

Few persons can bear an atmosphere loaded with aroma, whilst a little is occasionally refreshing; the same as a pocket-handkerchief saturated with otto of rose, soon

palls upon the sense, though the first diffusion of its odor might have been grateful.

In Autumn, during the ripening of fruits, the chemist ascertains that they in all cases tend to the production of carbonic acid; and as in the case of seeds which will not germinate, unless carbon escape from them, as shown at page 73; so in this of fruits, they will not ripen unless they can relinquish a portion of their carbon as carbonic acid; indeed they will rapidly die and rot, if their functions in this respect be prevented.

When fruits rot, they first change a portion of the oxygen of the air into carbonic acid, and then abundantly liberate carbonic acid ready formed, so that during Autumn both the ripening and decay of fruits become sources of carbonic acid in the atmosphere; this carbonic acid, the leaves of surrounding plants, if healthy, have the power of elaborating into matters conducive to their vitality, under the direct influence of solar light.

The seeds committed to the earth a few months since, watered by the gentle showers of Spring, warmed and nurtured by the sun of Summer, have attained their perfect structure during Autumn, and brought forth, some ten fold, others sixty fold, according to the nature and situation of the soil.

For example: if we now proceed to the plot of earth where the beans were first cast, for affording us the means of investigating the phenomena of germination by the death of one set of their proximate constituents for the quickening of others, we shall find such as remained undisturbed, have now grown up into perfect plants, with luxuriant foliage; and from the intervening stems are hanging numerous heavy pods, containing not each one

single bean, but six, or seven, or eight beans, all precisely identical in their physical and chemical characters, with those originally committed to the earth, and into which, by the bursting of the ripe pod, these in their turn will ultimately fall, and remain dormant during the approaching Winter, then will germinate, upon the return of Spring, flourish throughout Summer, ripen during Autumn, and then again, as now, display their multifarious store.

Fig. 52.

We shall thus find that the existence of most plants is dependent for its continuance on an inherent law, or principle of producing a seed similar to that from which it sprung; the perfecting of this seed is the grand object of the various processes and actions which take place from germination to maturity; and when it is completed, the end for which the plant was formed is probably accomplished; it either dies away, upon the seed previously relinquished, to which even in the putrefactive changes of death it affords nutriment, as its ultimate elements undergo new arrangements; or in place of thus entirely mingling with the earth, the dead leaves alone are cast upon it, for slow yet certain transition, into the food of future plants, whilst the stem and branches, though denuded, remain unharmed and dormant throughout the rigors of Winter, and resume the full exercise of their vital functions for the reproduction of

foliage, flowers, and fruits, as Spring, Summer, and Autumn, appear in unerring and ceaseless change.

How miraculous are the foregoing phenomena, and in minds duly prepared, how pure, how exalted, are the feelings of happiness and of faith inspired by their contemplation and investigation; they direct our thoughts from the present to an hereafter, and are appealed to in Scripture as emblematical of the "resurrection of the dead."

"But some man will say how are the dead raised up? and with what body do they come?

"Thou fool, that which thou sowest is not quickened except it die;

"And that which thou sowest; thou sowest not that body that shall be, but bare grain, it may chance of wheat or of some other grain:

"But God giveth it a body as it hath pleased Him and to every seed his own body," *et seq.*

"So also is the resurrection of the dead. It is sown in corruption: it is raised in incorruption," *et seq.*

In this general inquiry, it is impossible to dwell upon all the extraordinary matters that are presented to our notice during the season of Autumn; the mere examination of the proximate principles of vegetables would of itself occupy more space than is here devoted to the phenomena of all the Four Seasons.

The rich and varied products of cornfields, vineyards, orchards, and gardens, have been gradually elaborated by the recondite powers of vitality from the earth, the waters, and the air, under the genial agency of solar light and heat, directed by the Hand of Omnipotence, from the dawn of Spring, throughout the noon of Summer, unto the evening of Autumn; "the trees of the field

have yielded their fruit, and the earth has brought forth her increase" for the welfare and comfort of man, during the approaching night of Winter.

In reference to the power and goodness of God, who "fixes the mountains, calms the seas, and refreshes and fertilizes the earth, providing abundance of necessaries for the use of man," well does the inspired Psalmist exclaim, with rapture:

"Thou crownest the year with Thy goodness; and thy paths drop fatness.

"They drop upon the pastures of the wilderness; and the little hills rejoice on every side.

"The pastures are clothed with flocks; the valleys also are covered with corn; they shout for joy, they also sing."

The sun now declines in heat and splendor, the atmosphere becomes chilled, and leaves assume an endless variety of hues, thus presenting beauties even in their decay; these well-known autumnal tints are presumed to depend upon peculiar acid matters now formed in the leaves, which acting upon the principle that during summer caused the reflection of green light, so modify it as to produce a reflection of red and yellow light, and various intermixtures of colored rays.

The sight of a vast forest, thus variously tinted by the rays of the setting sun, is indeed magnificent; but the foliage soon loses its vital functions; the fall of the leaf arrives, and then the chill winds denude the trees, sweeping back their leaves to mingle with the earth, there to elaborate nutriment for the stems they once adorned.

During Autumn, we frequently see upon meadows, circles of green much brighter than that of the surround-

ing grass; these are popularly known as "fairy rings," and probably they are due to the growth of a fungus, which dying away every year, leaves a rich soil, upon which the grass grows more luxuriantly than upon other parts of the meadow; these rings, therefore, annually increase in size, and in many localities they present an extraordinary appearance.

Slight frosts are common towards the close of Autumn, and therefore tender or valuable plants require protection by matting, or other bad conducting covering; and at this season may be often observed in the fields, marks of footsteps, which appear to have scorched the grass like heated iron; this phenomenon was formerly regarded with superstitious dread, but can now be explained upon very simple chemical principles.

When the grass becomes crisp by frost, it is exceedingly brittle, and the foot of a man, or even of a child, is sufficiently heavy to break it completely down, and effectually to kill it; therefore when the sun has thawed the frosty rime from the fields, these foot-tracks appear brown and bare, in the midst of the surrounding and flourishing green grass.

Such are a few, and a few only, of the principal chemical phenomena of Autumn; and at its close, the frequent occurrence of frost warns us of the approach of Winter.

During the dark and dreary reign of this, the last of the Four Seasons, we shall still have to extol the power and appreciate the goodness of the Almighty, in providing for the welfare and protection of His creatures, although "the waters are hid as with a stone, and the face of the deep is frozen."

CHAPTER IV.

WINTER.

"He casteth forth His ice like morsels; who can stand before His cold?

"He sealeth up the hand of every man: that all men may know His work."

Decreasing days, gathering vapors, falling dews, piercing winds and chilling frosts, conclude the train of departing Autumn, and commence that of approaching Winter.

The most remarkable Chemical phenomenon of Winter, is the transition of water from the liquid to the solid state, and therefore its consideration will form the chief subject of this concluding Chapter.

The Chemist discovers, during his manifold experiments and researches throughout the varied productions of Nature and of Art, that all substances contract when cooled, and expand when heated; with the exception of water, which expands when cooled below a certain degree;—this departure from a law so general, or anomaly in the code of laws discovered by man, is productive of the most beneficial effects throughout the Creation; but to understand and duly appreciate these, a few preliminary experiments require to be performed, on the con-

traction and expansion of solids, liquids, and aëriform bodies generally.

Fig. 53.

First as regards solids:—Provide a smooth cylindrical bar of iron, about one inch in diameter and four inches in length, with a piece of iron wire about a quarter of an inch in diameter and ten inches in length, screwed into one of its ends, the other end of the wire being inserted into a wooden handle;—likewise a piece of iron-plate about three inches square, with a circular aperture in its centre, that will exactly allow the end of the cylindrical bar to pass through, or to use a more technical expression, that will "gauge the bar."

Mix together equal weights of finely-powdered ice, or snow and common salt, in an earthen or wooden bowl; this will form an intensely cold mixture, for a reason hereafter to be given;—place the cylindrical bar in this for five minutes; then remove it, wipe it with a cloth, and apply it to the gauge; it will enter with extreme readiness, and indeed will be perfectly loose, but in the course of a few minutes it will only enter as exactly as it did at the outset of the experiment.

Ascertain this fact, then withdraw the bar from the gauge, and place it for five minutes over a clear glowing fire, so that it may become heated, but not to a degree approaching redness; then remove it, and apply it to the gauge; it will be impracticable to cause its entrance, until it is cooled down to the temperature that it had originally.

In these experiments, the bar of iron is said to contract by cold; and to expand by heat.

The contraction and expansion of a liquid by cold and heat, may be thus experimentally demonstrated:—Pour spirit of wine into a Florence flask, leaving only about half an inch of the neck unoccupied; with a sharp file make a mark upon the glass, or paste a small slip of paper around it, at the level of the spirit; then place the flask in the mixture of ice, or snow and salt;—as the spirit cools, it will contract in bulk, and at length remain stationary considerably below the mark; ascertain this fact, then remove the flask, dry it with a cloth, place it to stand upon a ring, as at page 66. As it gradually gains warmth from the surrounding air, the spirit will expand, and ultimately become stationary, exactly at the mark;—now plunge the flask into hot water; the spirit will expand, and rise above the mark; but upon removal from the hot water, and cooling in the air as before, the spirit will contract to its original level.

The experiment may be varied:—Select a sound cork that will fit the neck of the flask, make a whole through

Fig. 54.

the center of the cork to admit one of the open ends of a piece of glass tube, about a quarter of an inch in diameter, and from ten to twelve inches in length.

Pour spirit of wine into the flask until it is brimful, then insert the cork into the neck of the flask, that the greater part of the length of the tube may stand uppermost;—in doing this, a portion of the spirit will rise in it, but a little more may be dropped in, that its level may be about two inches above the cork, and then any portion that has escaped should be wiped away.

The flask should be held by the neck, and not by the bulb, during the insertion of the cork; and this rule is invariably followed by the chemist, in corking or stoppering all bottles or other vessels that are employed in his experiments, in order that should they break, his hands may not be lacerated by their fragments, or corroded by their contents; it is seldom that the necks of flasks or bottles break, whilst their bulbs and cylinders very frequently do, therefore the necks remain between the fingers of the operator, and do no injury, and the only temporary inconvenience is the loss of the vessels and their contents.

The flask, prepared as directed, may then be cooled and heated, as above described; and in consequence of the elongation of its neck by the glass tube, the contraction of the included spirit by cold, and its expansion by heat, will be more perceptible; and if it be required to demonstrate this fact more plainly, the spirit of wine may be colored of a deep crimson, by a few grains of cochineal, and a slip of white paper pasted against part of the tube, to render the descent and ascent of the spirit yet more visible.

The contraction of air by cold, and its expansion by

heat, can be shown by an apparatus equally simple in its construction to that just described.

Make a teacupful of blue infusion, as directed at page 223; pour this into a flask; select a cork that will most accurately fit its neck; then perforate the cork, to admit of an open glass tube, the same diameter as the last, but thrice its length, being passed through until that part which protrudes from the lower end of the cork, when it is inserted into the neck of the flask, will dip about half an inch below the surface of the infusion that it contains.

If the cork be sound, and the perforation as truly cylindrical as the glass tube, the arrangement is complete; but the perforation can seldom be accurately made with a knife, and therefore the better plan is to bore a hole through the cork with an awl, and then to enlarge this very smoothly with a cylindrical rasp or file, until it fits the glass tube, care being taken, whilst thrusting it through to the length mentioned, to hold it in a folded cloth, lest it break.

Fig. 55.

Suppose the cork and tube inserted into the neck of the flask as above, a very simple test will detect if it be

all air-tight, viz., place the upper and open end of the tube between the lips, and then endeavor to force air down it; if this can be done easily, and if plenty of air bubbles appear through the infusion, the apparatus is leaky; if, on the other hand, it can only be done with difficulty, and but few bubbles appear, and above all, if upon removing the lips from the tube, the infusion rise in it considerably above the level of that in the flask, and remains stationary, when the flask is held by the neck, the apparatus is "air-tight," and fit for use.

Should the infusion descend rapidly in the tube, the whole of the upper part of the cork, part of the tube that it immediately surrounds, and the neck of the flask for about a quarter of an inch, must be covered with strong glue, or a solution of sealing-wax in spirit of wine, to stop up all pores or fissures; and when either application is dry or set, the apparatus may be tested by endeavoring to force in air; and if the infusion rise and remain stationary in the tube, the flask being held by its neck, all things are favorable to the success of the following experiment.

The flask contains a certain volume of air, and it presses with a certain force upon, and sustains a certain column of the infusion; now plunge the bulb into a vessel containing ice-cold water; its degree of cold will immediately cause the volume of air to contract, and diminish its pressure upon the infusion, consequently that in the tube will fall; allow it to do so, until it fall to the level of the main bulk of that in the flask; then quickly remove this from the ice-cold water, and plunge it into a vessel containing water that has remained for many hours in the apartment in which the experiment is made,

and therefore has acquired its temperature; the volume of the air in the flask will now expand by the increase of heat, and press upon the surface of the infusion in the flask, and force a portion of it upward in the tube to the same level as that at which it stood previously to being cooled.

Ascertain these facts; then remove the flask, and plunge it into a vessel containing water that has just been taken boiling from the fire; the volume of air will instantly expand by this great increase of heat, and press so forcibly upon the infusion in the flask, as to force a portion of it upward, nay even to the very top of the tube; when this happens, quickly remove the flask, place it to stand on a ring, as at page 66, and as it cools, the air will gradually contract in volume, its pressure will gradually lessen, the infusion will slowly fall, and at length arrive and remain stationary at the original level that it assumed when the flask was plunged into water having the same temperature as that of the apartment.

This apparatus or "air-thermometer," will present the same phenomena repeatedly, care being taken, if necessary, to force in a little air as directed; and during experiments with it, as in those experiments at page 65, the included volume of air sustains nothing beyond mere physical contraction by cold, and expansion by heat; it sustains no chemical change in the proportions of its elementary and compound constituents; it will support the flame of a taper, as at page 66.

If the infusion become mouldy or putrid by keeping, then the air above it will not support the flame of a taper, because the decomposition of the organic coloring matter has altered the relative proportions of oxygen and nitrogen; and this is a chemical change.

Absolutely pure water undergoes no change by any lapse of time if kept in vessels, the materials of which have no attraction for its oxygen or its hydrogen, such as Florence flasks of hard glass, or yet better, bottles of gold or platinum, these metals having the feeblest attraction for oxygen of all known substances.

The unpleasant odor of rain-water, as it is commonly collected, depends upon the decomposition of the organic matter that it has washed from the roofs of buildings, or that it has acquired from the casks and tanks in which it is kept, whilst water chemically pure, or containing metallic compounds in solution, will remain unchanged for years, nay, for ages, as exemplified by the fact of its natural occurrence within crystals and pebbles of silica, which extraordinary substance, thus densely aggregated, has no attraction for water or its elements.

Silica, when its attraction of aggregation has been destroyed by some occult process in the vast and perfect laboratory of Nature, is then rendered soluble in water, as exemplified in those extraordinary and wonderful waters, known as the "boiling fountains," or "Geysers," in the vicinity of the volcanoes of Iceland.

The waters of these fountains gush boiling hot from the earth, and as they fall and evaporate, leave a silicious incrustation upon the sides of the natural cavities into which they are received, and upon the surrounding peat, mosses, and grass; the leaves of birch, and other stinted trees which grow in that severe climate, are also incrusted, so as to appear as white as stone, or petrified, yet preserving not merely their general form, but their minutest fibres, unaltered.

The petrifying springs of England deposit not silica,

but carbonate of lime, upon their courses, and substances that are immersed in them; for carbonate of lime, although insoluble in pure water, is soluble if it contain excess of carbonic acid; and as this escapes by exposure to the air, the carbonate of lime falls, as an insoluble solid or petrifaction; this can be imitated by the artificial operations of the chemist, but he is ignorant of the natural process by which the phenomenon of the solution is effected.

Let us now return to the more immediate object of our inquiry, viz., the contraction and expansion of solids, liquids, and air, by cold and by heat.

The chemist, by conducting experiments similar in principle to those described, but with refined apparatus, and with his utmost skill in manipulation, arrives at the conclusion that air, and all aëriform substances, gases, and vapors, when cooled or heated out of the contact of the liquids from whence they were educed or produced, contract alike, and expand alike; but as regards solids and liquids, he discovers that they have distinct contractions by cold, and expansions by heat.

Or in other words, if a definite volume of air at common temperature, *i. e.*, 62 degrees, contract into a less volume by the cold of iced water, and expand into a greater volume by the heat of boiling water, a similar definite volume of chlorine, hydrogen, or carbonic acid, will do precisely the same; if, on the other hand, a definite bulk of liquid mercury contract into a less bulk by the cold of iced water, and expand into a greater bulk by the heat of boiling water, a similar definite bulk of alcohol, submitted to such variations of temperature, will contract six times, and expand six times more in its bulk than mercury; and lastly, if a definite mass of iron

contract and expand to a definite mass by cold and heat, a similar definite mass of lead will contract and expand three times more in its mass than iron.

Having conducted these few preliminary experiments, we may now proceed to investigate the extraordinary exception that water presents, to this general law of contraction by cold and expansion by heat.

Provide a Florence flask, with a long neck, yet capable of admitting the bulb of a delicate mercurial thermometer;—pour water at the temperature of 80 degrees into the flask, until about two inches of its neck remain unoccupied; place the thermometer with its bulb dipping below the surface of the water, that the scale may rest upon the mouth of the flask; then make a mark, as already directed, on the glass at the level of the water, and lastly, lift the flask into a quart jar, containing a mixture of ice and salt sufficient to surround the bulb.

As the water cools from 80 degrees, it will contract and fall in the neck of the flask, like the spirit in a former experiment;—let the thermometer be closely observed all this time; the water will continue to contract until it attains the temperature of 40 degrees, and at that moment the water, instead of continuing to contract, will slowly expand, and rise in the neck of the flask, until the thermometer indicates a cold of 32 degrees, and then the water will congeal or freeze; mark the level of this newly-formed ice upon the neck of the flask, then immediately withdraw it from the cold mixture, wipe it dry, and place it on a ring, as already directed.

This is a remarkable experiment, and the knowledge that emanates from its accurate investigation is of great importance;—the water, when it contracts by cold to the

temperature of 40 degrees, is said by the chemist to attain its maximum of density;—he means by this expression, that if it be cooled below 40 degrees, or heated above 40 degrees, that its contraction and expansion will be similar.

Suppose, for example, the ice in the flask of the last experiment be allowed to thaw, the thermometer after some hours will indicate when the temperature of the water has risen from 32 degrees to 40 degrees; or has attained its maximum of density; as it becomes warmer it will expand, and upon attaining the temperature of 48 degrees, it will rise to the same mark, or be of the same bulk as it was at the cold of 32 degrees—or in other words, at 8 degrees above 40, the maximum of density, or at 8 degrees below, water is of the same bulk.

With this incontrovertible fact in chemistry we are enabled to venture upon an interpretation of the transition of water from the liquid to the solid state during the natural cold of Winter.

If water, like other congealable liquids, continued to contract in bulk, and to increase in density until it froze, large bodies of water, instead of only being superficially frozen in Winter, would become solid masses of ice. Let us select a fresh water lake as an example;—in Winter, the earth, as already stated, (page 77,) is warmer than the air; the heat is accordingly withdrawn from the surface of the water by the cold breezes that blow over it; the water, thus cooled, increases in density and falls, whilst warmer water ascends, to undergo a similar abstraction of heat in its turn; and these descending and ascending, or convective currents, continue, until the entire bulk of the water has attained the temperature of

40 degrees,—its maximum of density and temperature perfectly congenial to aquatic beings.

The cold breezes still blow over the surface of the lake, still abstracting heat, but instead of causing the water to contract or become heavier, as it would every other liquid, it actually causes it to expand and become lighter, so that cold water fairly floats upon warm water, with no more power of sinking through it than a film of oil would have.

This stratum of light cold water cannot communicate depression of temperature to the warmer water beneath, because it has no conducting power, and convective power is out of the question; it therefore remains floating until cooled by the breezes to 32 degrees; at this temperature it has parted with so much heat, that it can no longer remain liquid, and therefore, becomes a solid sheet of ice.

Over this newly-formed surface the winds may continue to blow, with their greatest intensity of winter cold, but it shields the liquid water upon which it reposes from their chilling agency, and preserves it immutably at the temperature of 40 degrees, whatever may be the cold of the ambient air, for ice is a non-conductor.

The temperature of the surface of the ice may fall many degrees below 32 degrees, but the water beneath remains at 40 degrees; accordingly fishes dwell securely in these warm liquid depths until the heat of spring dissolves the icy shield, and then they rise upon the surface of the emancipated waters.

Had the Creator ordained that water should thoroughly cool to its freezing point, by direct conduction of cold from the air, then on the first approach of Win-

ice and salt; they are thus exposed to the same degree of cold, and the water will freeze at 32 degrees, but the brine will remain liquid at this temperature, and many degrees below it, as the introduction of a thermometer will prove.

The chemist, by discovering that saline matter present in water thus causes it to resist congelation, is led to consider the ocean as being an enormous magazine of heat; and that it enacts an important part, in yielding heat, for the mitigation of the inland cold of Winter.

Several curious and instructive experiments can be made regarding the phenomenon of the congelation of fresh water; in the first place, provide a cylindrical glass about two inches in diameter, and fifteen inches high, open at one end and closed at the other by a broad "welt," or foot, upon which it will stand firmly.

Into this glass, pour water at 40 degrees, until within four inches of its brim, then introduce a few lumps of clean ice which will float upon the water, and at the same time raise its level coincident with that of the brim of the glass; allow this arrangement to remain for a few minutes that the ice may slowly thaw.

Whilst this thawing is proceeding, detach the delicate thermometer from the brass column of the "hygrometer," page 175, and to its upper part attach a slender string about eighteen inches long, and by this carefully allow the thermometer to descend, through the water, to the bottom of the cylindrical glass, and note the temperature, probably 40 degrees, that is indicated.

Then gradually draw the string, to raise the bulb of the thermometer into the water resulting from the thawing of the ice; and its entrance into this peculiar stratum of water will be known by its indicating a temperature

of about 33 degrees. Why is this curious phenomenon presented?

Because ice-cold-water, or nearly ice-cold-water, is lighter than the warmer water, upon which it floats like a film of oil; again, allow the thermometer to descend from this stratum, and its mercury will ascend by the action of the comparative warmth to which it is subjected; again, cause the thermometer to ascend, and its mercury will descend by the action of the comparative cold to which it is subjected; and thus the extraordinary yet important conclusion is obtained, that within certain ranges of thermometric temperature, cold water will float upon warm water instead of *vice versâ*, as in the case of all other liquids.

This experiment being concluded, the water may be poured away from the jar, and then the following arrangement can be made, in further illustration of the lightness of ice-cold-water and ice, and the non-conducting power of water.

Select a well-shaped flower-pot, the upper part of which is from six to seven inches in diameter; then with a circular rasp, enlarge the aperture of its lower part, until it will just admit of the entrance of the cylindrical glass, that its brim may stand a quarter of an inch above the level of the brim of the flower-pot.

A piece of broad tape, about three feet long, must be wound tightly around the part of the glass that protrudes from the lower part of the flower-pot; and then coated with a thick mixture of plaster of Paris, to unite the surfaces firmly, and form a water-tight joint;—this will be effected in the course of an hour or two, by the hardening or setting of the plaster; the glass may then

be placed to stand as before, but supporting the flower-pot around its upper part.

Fig. 56.

Thrust a ball of lamp-cotton or a thin sheet of crumpled paper into the mouth of the glass; then fill the space in the flower pot with a mixture of finely powdered ice and salt, as already directed, and should the arrangement seem likely to fall on account of such a considerable and enlarged weight being placed so much above the small or limited point of support afforded by the glass, a heavy brick must be placed on opposite sides of its "welt," or foot, and thus render its position firm and upright.

Remove the temporary stopper of cotton or paper, taking great care that none of the mixture of ice and salt fall into the glass, then pour water at common temperature into it, until within an inch of its brim.

This simple arrangement will enable us to imitate with rapidity, upon a microscopic scale, the phenomenon that proceeds with slowness throughout the gigantic laboratory of Nature, during Winter, because in both cases the source of cold is applied at the surface of the water; only in the artificial case it is derived from a mixture of ice and salt, and in the natural case, from winds of extremely low temperature.

Take the suspended thermometer, as already employed, and immerse it at different depths of the water from time to time, and remark that it indicates the power of the cold mixture in reducing the temperature uniformly down to 40 degrees, because those portions of water in immediate contact with the source of cold, lose heat, contract, and therefore fall, whilst warmer portions ascend; they in turn become cooled and fall; convection, and not conduction, is thus established, until the entire bulk of the water is cooled to 40 degrees, or its point of maximum density.

Having attained this maximum of density, the process of further cooling is no longer extended throughout the entire bulk of water, but is confined to that portion only in immediate contact with the source of cold, which continues constant, it is true, but in place of producing a greater contraction of the water, now induces expansion; this will be immediately detected by the water rising near the brim of the glass.

Thus the cold water is lighter, and floats upon the warmer that is heavier; the thermometer, which indicates 40 degrees at the bottom of the glass, will soon indicate a cold of 32 degrees at or near the top; and when this happens, the water can no longer remain liquid, but will congeal into a solid cylinder of ice, extending from the top to the bottom of the mixture of ice and salt, whilst the water from the lower part of the flower-pot to the base of the glass, will remain liquid; because it is of the higher temperature of 40 degrees, and is incapable of conducting cold.

If the arrangement be now dismantled, by pouring away the mixture of ice and salt, and wiping the outside of the glass cylinder dry with a cloth, not only will the

danger of its fracture be prevented, but the mass of ice that it encloses will be distinctly seen.

If the source of cold be applied around the lower part of the glass cylinder when filled with water at common temperatures, the effect is very different, for the cooling below 40 degrees renders the water lighter; it ascends, whilst warmer descends, becomes cool in its turn and ascends; thus convection is established throughout the entire bulk of water, or thus its entire bulk is cooled to 32 degrees, and it will become solid ice throughout its entire bulk; an effect limited to the mere surface of the water in the last experiment, and which, as already stated, represents what happens in Nature where the cold is always superficial, and ice being lighter than water, floats upon its surface.

If the weight of a bulk of Water be = 1000, the weight of a similar bulk of ice will be = 940, or in other words, its inherent or particular weight is less than that of Water; accordingly, the chemist says that the Specific Gravity of Ice is less than the Specific Gravity of Water; he denotes by this technical expression, the comparison of the weights of equal bulks of different substances, in reference to some fixed standard: let us endeavor to understand his precise meaning.

Suppose a measure so accurately constructed, that its capacity is exactly equal to a Cubic foot; suppose the tare of this vessel be accurately taken, and that it be perfectly filled with pure water at the temperature of 62 degrees; this bulk, measure, or cubic foot of water, will weigh 1000 ounces avoirdupois; this weight is adopted as a Standard of Unity, because Water may be obtained, though not absolutely pure, yet sufficiently pure and abundant for all practical purposes.

If the water be removed from this cubic measure, and its place supplied with Sea-water, 28 ounces will generally be required as an addition to the 1000 ounces, before an equilibrium is effected, so that the weight of a cubic foot of sea water will be 1028 ounces. If the sea-water be removed and a solid block of ice be accurately wrought to fit the cubic measure, 88 ounces must be taken from the 1028 to effect a balance, therefore a cubic foot of ice will weigh 940 ounces.

Sea-water is therefore heavier, and Ice lighter, than Water; and the numbers 1028 and 940, directly express their relative weights to it, or their Specific Gravities, the one being 28 thousandths heavier, and the other 60 thousandths lighter than water, or more concisely expressed by decimals, as thus: Specific Gravity of Water = 1.000 of Sea Water = 1.028, and of Ice = 0.940.

Thus, having fixed upon Water as a Standard, and proceeding to ascertain the Specific Gravities of various liquids and solids, the chemist discovers that very few of them exactly coincide with each other; for example, Spring-water, containing a small amount of chloride of sodium and sulphate of lime, has a Specific Gravity, or for the sake of brevity, S. G. 1.001.

Water of the Dead Sea containing much chloride of sodium, chloride of magnesium, and chloride of calcium, S. G. 1.211; Water saturated with chloride of sodium, forming Brine, S. G. 1.220; these differences in Specific Gravities being dependent upon the fact of a greater actual weight of matter being contained within the same bulk in some cases than in others; thus, all saline substances, such as chloride of sodium, chloride of magnesium, and carbonate of potash held in solution by water,

increase its Specific Gravity, until it is saturated or can dissolve no more; thus, Spring-water is a weak solution, and its Specific Gravity barely exceeds that of water, Sea-water is a strong solution, Water of the Dead Sea a stronger solution, and these both exceed the S. G. of Spring water, whilst Brine, which is the strongest solution of them all, in fact a saturated solution of chloride of sodium, exceeds even the S. G. of the Water of the Dead Sea.

All common acids when they saturate water, likewise increase its Specific Gravity: we have already employed three of these; viz., Hydrochloric acid S. G. 1.210, Nitric acid S. G. 1.500, and Sulphuric acid S. G. 1.840, this being nearly twice the S. G. of Water.

When water is added to dilute these concentrated acids, as in the case of sulphuric acid, at page 220, the S. G. of the mixture is materially lower than 1.840, though invariably higher than 1.000, or the Water standard.

Ammonia is an alkaline vapor, and when it saturates water, the solution, in place of becoming heavier, becomes lighter, in fact, from being 1.000, it is reduced to .875, and this is about the S. G. of Alcohol or spirit of wine.

The fact that equal bulks of different liquids have different weights, may be thus experimentally illustrated: take the tare of an ounce narrow-mouthed vial, then fill it with water, and ascertain the weight of such water in grains; pour it away, and fill the bottle with sea water, ascertain its weight, which will be materially greater than that of the water; then with the spirit of wine, which will be lighter; and so on with other liquids, very

few of which will be found to agree in their Specific Gravities.

If the experiment be made with Mercury, a very common pair of scales should be employed, because its extreme weight would break the strings or bend the beam of a delicate balance such as the chemist uses in accurate experiments, and render a valuable instrument perfectly worthless.

Suppose the experiment made with Mercury, and with Spirit of Wine, the following formula will discover the Specific Gravities of these liquids compared with that of Water.

Divide the weight of the Mercury, and of the Spirit of Wine, decimally by the weight of the Water, which the bottle originally held; thus, suppose it originally held 425 grains of Water, and it be found to hold 5737·5 grains of Mercury, and 350·5 grains of Spirit of Wine.

5737·5 ÷ 425 = 13·5, the Specific Gravity of Mercury;
and 350·5 ÷ 425 = 0·824, the Specific Gravity of Spirit of Wine.

A very homely yet tolerably accurate method is often adopted for ascertaining when brine is sufficiently strong for the preparation of meat for salting, or of vegetables for pickling; it consists in the fact, that an egg will sink to the bottom of spring or river water, but will float upon the surface when as much common salt is added as the water can dissolve; the egg thus becomes a "hydrometer," or measurer of liquid strength, and upon this simple principle a refined instrument, bearing that name, is constructed for ascertaining with celerity and accuracy, the specific gravities of saline solutions, acids, worts, and of spirituous liquors more particularly.

The annexed engraving shows the usual form of the hydrometer, which is constructed of glass or metal, according as it is intended to be employed for taking the specific gravities of corrosive or neutral liquids.

Fig. 57.

It consists of a hollow bulb in the form of an egg, with two stems of unequal length, the longest proceeding from the larger, and the shortest from the upper end; this latter has a small bulb at its extremity, and it is either originally made sufficiently heavy, or is ballasted within, by a globule of mercury or a few small shot, that it may cause the larger bulb and stem to float upright when plunged into a liquid, just the same as the piece of lead that is nailed on the keel of a schoolboy's boat, causes it to float with its mast upright on the water of a pond; this is the form of the "hydrometer."

The tall cylindrical glass for the experiments, described in pages 304, and 305 is technically called a "plain hydrometer glass;" if it have a lip on its brim for the convenience of pouring, it is called "a lipped hydrometer-glass;" this form is not so convenient for the above experiments, as the lip interferes with the accurate fitting of the flower-pot around the cylindrical part of the

glass, but is very advantageous when it is to be employed for holding any liquid the specific gravity of which is to be denoted by the "hydrometer."

Suppose the "hydrometer-glass" nearly filled with water, and the "hydrometer" immersed with the shorter stem and small bulb downwards, the instrument will gradually sink until the large oval bulb, and part of the longer stem, become immersed; a mark is therefore made upon it, coincident with the surface of the water; this is a "standard mark," and indicates the depth to which the "hydrometer" will always sink in pure water, having a specific gravity of 1.000, at 62 degrees of temperature; a number of equal divisions being marked above and below this "standard mark," the depth to which the longer stem sinks will show whether any other liquid into which the "hydrometer" is plunged, is lighter or heavier, or has a specific gravity below or above that of water.

Thus, in Alcohol, it would sink so low as to submerge nearly the whole of the longer stem,—the same as the egg would sink through spring water,—whilst in the water of the Dead Sea, it would rise so high as to leave the "standard mark" considerably above the liquid surface, the same as the egg would float upon the brine.

By repeated immersions of the "hydrometer" in liquids and solutions, the specific gravities of which have been previously determined by accurate weighing in the "specific gravity bottle," real specific gravities may be marked on the stem of the instrument, and thus immediately read off with rapidity, and with sufficient accuracy for all ordinary purposes.

Another familiar example of the case in point, is the fact, that it is much easier for a person to swim in sea

water than in river water, because the human body, like the egg on brine, is buoyed up in a greater degree in the one case than in the other; and, indeed, if a boat were so laden as to float with safety on the water of the ocean, it would sink upon arriving on the water of a river.

This may be proved by placing the schoolboy's boat upon brine, and gradually and evenly loading it with sand until it just floats level with the solution's edge; then carefully lifting up the boat, and gently placing it upon river water, it will instantly sink.

Many other extremely beautiful and instructive experiments can be made by very simple means for illustrating this important subject of Specific Gravity; for example, place the pipe of a "wine-strainer" in an ale-glass, that it may quite touch the bottom, then pour down brandy sufficient to occupy half the capacity of the glass, and having done so, slowly pour down sufficient water to occupy the remaining half, and then remove the "strainer;" the difference between the specific gravities of the two liquids will be strikingly shown, by the colored brandy floating on the colorless water; and yet further demonstrated, if a lump of white wax, about

Fig. 58.

the size of a hazelnut, be placed upon the brandy, the wax being of greater specific gravity than it, will sink;

eing of less specific gravity than the water, will
ıpon its surface.

the tall "hydrometer" glass be thoroughly cleaned
ried; then select a piece of pewter, copper, or glass
about two inches longer than the glass, and having
: about the size of a goose-quill, and if such can-
: obtained, a hollow reed, or even a piece of large
ermicelli may be substituted; one end of the tube,
ver be its material, is to be placed at the pipe of a
glass funnel and secured by gluing a strip of calico
l it, the object being to elongate the pipe of the
, that it may touch the bottom of the "hydrometer
" in which it is to be placed, as here shown; the
: at the bottom of the glass will be described
ter.

Fig. 59.

:e half a pint of rain water in one finger glass, and
pint in another; add to the one as much "White
," *i. e.*, sulphate of zinc, and to the other as much
vitriol," *i. e.*, sulphate of copper, as it will dis-
or, in other terms, obtain saturated solutions of
substances, which are known to the chemist as
;," although they differ from "common salt" in

chemical composition, and all physical properties, save those of solidity and solubility in water.

By stirring these salts, then, from time to time in the course of a few hours, the desired point of saturation will be gained, and it is indicated by a considerable proportion of each remaining undissolved.

Mould three lumps of wax into the size of hazelnuts; take one of these, and introduce into it a few shot, that will render it sufficiently heavy to sink through water, but yet to float upon the solution of "blue vitriol;" this is easily done after a few trials: take another lump, and introduce into it a few more shot, that will render it sufficiently heavy to sink through the solution of "blue vitriol," but yet to float upon the solution of "white vitriol;" then wash these lumps of wax in water and dry them with a cloth.

Make a cork ball, and select a leaden bullet, of the same size as one of the lumps of wax; heat the bullet slightly, and rub a piece of wax upon it to form a thin coating, or it may be "black-leaded."

Place all the lumps of wax, the cork ball, and the bullet at the bottom of the "hydrometer-glass," as shown in the engraving; color about four fluid ounces of strong alcohol of a fine crimson, with a few grains of cochineal; this forms what is called a "tincture," to denote that it is a solution of coloring matter, in spirit or alcohol, instead of in water.

Strain the "tincture" from the dregs, through a piece of fine muslin, and gently pour about half into the funnel; it will descend through the long pipe into the glass, and the cork ball will float on it; next, slowly pour in about the same bulk of water, and the plain lump of wax will rise and float on it; then, with the same precaution,

r in about the same bulk of the solution of "blue ol," and the lump of wax containing the least shot rise and float on it; proceed similarly with the solu- of "white vitriol," and the lump of wax containing most shot will rise and float on it; the leaden bullet e remaining; but, lastly, upon pouring in mercury, bullet will rise and float upon its surface, as buoyantly ie cork upon the tincture or the lumps of wax upon other liquids. Remove the funnel and the arrange- t will present the extraordinary appearance of five nct liquids contained in one glass, in the exact order eir specific gravities; and five solid masses floating fferent heights; the liquids keep so perfectly distinct a casual observer might think it was a glass, banded, tervals, with crimson, blue, and silver.

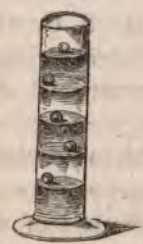

Fig. 60.

he surface of the bullet is covered with wax, or k-leaded, to prevent the lead from dissolving in the ury, for which it has a strong attraction; and the t specific gravity of the mercury is shown, not only e lead floating on it, but by its supporting the weight ll the other liquids; some days will elapse before mingle, and then no repose will cause their separa-

Substances insoluble or nearly insoluble in water, have mostly a greater specific gravity than it; thus as regards the earths, viz., Silica S. G. 2·660, Alumina S. G. 2·000, Lime S. G., 2·300, Magnesia 2·300; and it is on account of the great Specific Gravities of these earths and likewise of their natural compounds, that they chiefly subside with rapidity or precipitate from water when mechanically diffused throughout it by the force of inundations, or floods, the effects of which have engaged our attention at page 140.

But earths and their compounds are not the heaviest solid forms in comparison with water as a standard; the elementary metals best known surpass them all, as the following statement will prove.

Zinc S. G. 7·000, Iron S. G. 7·780, Copper S. G. 8·890, Silver S. G. 10·470, Lead S. G. 11·350, Mercury S. G. 13·500, Gold S. G. 19·25, and Platinum S. G. 21·00, this last metal being the heaviest substance either natural or artificial that the chemist has discovered.

Some idea of the relative Specific Gravities of solids may be gained by the performance of the following simple experiments; take the tare of a tin cup capable of holding about an ounce of rain-water, and then ascertain exactly how many grains this water weighs; it will afford a standard of comparison: pour away the water, dry the cup perfectly, remove all weights excepting those of the tare from the scale, fill the cup with fine Sand, and ascertain its weight; then proceed similiarly with fine filings of the following metals, viz., Tin, Zinc, Iron, and Lead, and it will be discovered, although all their bulks are nearly equal to that of Water, their weights greatly surpass it; and by finding how many times the

weight of the water is contained in each of their respective weights, an approach to their respective Specific Gravities will be obtained.

A more accurate proceeding is to obtain a solid cylinder of sandstone, and of each of the metals, exactly equal in bulk to the capacity of the tin cup; then having ascertained the weight of water that it will hold, to remove the cup and all weights from the scale, and simply to weigh the cylinders in succession, and then calculate how many times the weight of the water is contained in their respective weights; thus their Specific Gravities will directly appear, and will be nearly coincident with those already stated as belonging to these solid substances.

These remarks regarding Specific Gravity must not be carried further at present; let us return to the fact from whence they emanated, namely, that the Specific Gravity of Water being = 1·000, that of Ice is = 0·940, or in other words, Ice is lighter than Water.

Whatever fluctuations may happen in the density of the atmosphere, they produce no fluctuations in the degree of temperature at which liquid water becomes solid ice, or, in more popular terms, the degree at which water freezes; and the Chemist avails himself of this immutable fact, in the construction of the thermometer that we have employed so frequently during this examination of the chemical phenomena of the Four Seasons.

When the bulb and tube of the thermometer are supplied with a proper amount of mercury, it is immersed in melting ice, until the mercury contracts and becomes stationary; a mark is made upon the tube at this point; and whenever the instrument is again exposed to the

same degree of cold, the mercury will descend to the same point.

If the thermometer be plunged into boiling water, (under certain conditions to be described,) the mercury will expand, and rise, and at length become stationary; a mark is then made upon the tube at this point; and, generally speaking, at any future time it will rise to this mark when plunged into boiling water.

If the thermometer be immersed in a mixture of ice and salt, the mercury will contract and descend far below the point that it indicated in the melting ice, and this it will do at any future time; the mixture of ice and salt was formerly imagined to cause the absence of all heat, or to be "absolute cold;" it was therefore taken as the "zero," or commencement of the thermometric scale of degrees, perfectly arbitrary in their magnitude, but thirty-two of them included between "zero" and the "freezing point," and one hundred and eighty between it and the "boiling point" of water; so that 32 degrees became the thermometric expression for the "Freezing Point," and 212 degrees for the "Boiling Point."

The freezing point of water is immutable, but not so the boiling point; it is subject to variations from fluctuations in the local density of the atmosphere, and is therefore determined upon the thermometer scale, when the mercury in the barometer stands at 30 inches; this height indicates the mean pressure of the atmosphere, or announces that it is exerting a pressure of Fifteen pounds upon every square inch of surface; under such pressure, pure water boils at 212 degrees.

If the atmosphere become more dense, the boiling point will be elevated; if it become more rare, the boiling point will be depressed; the Barometer indicates these

aërial fluctuations; its mercury is highest during clear, bright days, and lowest during the prevalence of moisture; all persons are familiar with this fact, for the instrument is constantly examined during the Four Seasons; but many, when informed minutely concerning the construction of the barometer and the principle of its action, cannot readily understand why the mercury, or "the glass," to use the favorite expression, "falls when the day is dull and wet," and as they say "the air is heavy with water."

The Chemist can present a solution of this seeming difficulty or anomaly. It is true that water is about eight hundred and fifteen times heavier than air, but in this state of liquid density it does not exist in air; it exists as vapor, lighter than air in about the proportion of ten to sixteen; and accordingly air, saturated with such vapor, is specifically lighter than a similar volume nearly anhydrous or dry, and as a consequence, is unable to counterpoise or balance so tall a column of mercury.

On the plate of the household Barometer, or "weather-glass," the center is marked FAIR, above this SET FAIR, yet higher, VERY DRY, then below FAIR, is CHANGE, below it, RAIN, then MUCH RAIN, and lastly STORMY; these marks are entitled to no attention, and they never receive it from scientific observers, who know that the instrument can only indicate the actual weight of the air, and it is expressed by the numbers 31, 30, 29, 28, and their decimal subdivisions marked upon the scale.

If the favorite words of the instrument are to be relied upon, they actually state that similar changes of weather can never take place in any two situations. For example; suppose two excellent barometers, alike in every re-

spect from the hand of the same maker; they are suspended side by side in his workshop, and the rise and fall of the mercury in the one exactly tallies with the rise and fall of that in the other.

They are purchased by two persons, one resident on a hill, the other in an adjacent valley;—each barometer is placed in the house of its owner, consequently one is at a greater altitude from the level of the sea than the other.

The owners of these Barometers meet, upon a fine bright day; he from the hill-top prognosticates wet, because "the glass is low at RAIN;" whilst he from the valley predicts a continuance of fine weather, because "the glass is high at FAIR;" both losing sight of the different circumstances under which the instruments are placed.

The weather is the same on the hill and in the valley; but the weight of the air is not; it is less on the one locality than in the other, and to this cause alone is the discrepancy between the indications of the barometer to be referred; bring them side by side in either situation, they will immediately agree as they did in the workshop of the instrument-maker, be the weather fair or foul; restore each to its place again, and they disagree, although each is correctly indicating the weight of the air in its locality.

The Barometer and the Thermometer are two distinct instruments, and have distinct principles of action; the one indicates fluctuations in the weight of the atmosphere alone, the other changes in its temperature, or in that of surrounding objects.

Let us now return to the curious phenomena attendant upon the freezing of water in Winter;—the Chemist discovers that the formation of ice is attended with most

powerful expansion, and of its effects several familiar examples will readily present themselves;—we frequently find water in our bottles, not only densely frozen during frosty weather, but the bottles broken, or pipes for the conveyance of water split and rent asunder; if we reflect upon these occurrences for a moment, we must be convinced that a great force is brought into action during the congelation of water.

It is common to say, "that the bottles and pipes are broken by the frost;" true, not however by the mere cold of the frost, but by the expansion of the water in freezing, which these vessels, and others of far greater strength, are unable to withstand; this can be proved by experiment.

Boil half a pint of water to expel the air that it contains; allow it to cool down to the temperature of the atmosphere; in the mean time select a thick glass bottle, that will hold about four ounces, and a sound cork that will fit its neck accurately; pour the cold water into the bottle until it is quite full; then fold a thick cloth several times around it, and holding this firmly with one hand, thrust the cork into the neck of the bottle with the other, to the perfect exclusion of every bubble of air; secure the cork by tying it down with a string, and carefully wipe away any water that may adhere to it or the neck of the bottle.

The use of the cloth is to prevent the hands from being wounded, should the bottle break during the insertion of the cork; but suppose this has been done without accident, it must be dipped into hot cement, made by melting four parts of rosin and one part of wax, so that it may be firmly cemented to the neck of the bottle.

When the cement is cold, place the bottle in a mix-

ture of ice and salt, to cover it completely; this intense cold will not cause any fracture, but in the course of a few minutes, a sharp crack will be heard, which announces, that the water has frozen, expanded and broken the bottle, as will be evident upon removing it from the mixture.

Provide a bottle of wrought iron, about one inch in diameter, four inches long, and an eighth of an inch thick, having a female screw cut in its neck, and a male screw plug to fit this accurately; fill the bottle with boiled water, insert the plug as tightly as possible, and then submit it to cold, as last directed; when the water freezes, it will expand and burst the iron.

Many excellent and remarkable experiments have been made upon this expansive force of water in freezing;—cast-iron bomb-shells, thirteen inches in diameter and two inches thick, were filled with water, and their apertures or fuse-holes firmly plugged with iron bolts; thus prepared, upon exposure to the severe cold of a Canadian winter, between four and nineteen degrees below "zero," at the moment that the water froze, the iron plugs were violently thrust out, and the ice protruded, and in some instances the shells burst asunder; thus demonstrating the enormous interior pressure to which they were subjected, by water assuming its solid state.

Our attention must now be directed to the beneficial effects that result throughout Nature from this expansive force freezing of water.

During Spring, Summer, and Autumn, fertile soils by capillary attraction absorb and retain water for the support of their produce; during Winter, a portion of this water at the surface of the soil freezes, and by its expansive force thrusts the individual particles apart, and

so hold them apparently as solid clods of earth; but as the warmth of Spring returns, the icy cement dissolves from its interstices, the clods crumble down so minutely divided, as materially to lessen the labor of the husbandman in preparing the soil for seed.

The rounded or weather-worn aspect, the degradation or decay of many rocks, more particularly those of limestone and sandstone, may be referred to the exertion of this singularly powerful agency of water; it is absorbed into their fissures and pores by capillary attraction, as already shown, and when it freezes during Winter, it expands and detaches successive fragments, so that the original sharp abrupt outline is gradually rounded, and softened down.

Again, as regards slate-rocks, the strata of which repose upon each other like a number of cards placed at a certain angle or inclination, when water freezes in their fissures, fragments are detached; and thus freed from restraint, they glide down the sides of the parent mass, and accumulate as an enormous heap of ruin at its base.

During an extremely severe Winter the sap of trees becomes frozen, and the expansion attendant upon such change is said to rend them asunder with loud cracking or explosion;—we also observe illustrations of this phenemenon upon a minor scale, by flag-stones and pavements, suddenly starting from a level position, and the mortar of walls peeling away in flakes; and masons being aware of this fact, never undertake work requiring mortar or cement during the continuance of frost, or in the course of a few hours it would be destroyed.

If a large cubical piece of Bath-stone be perfectly saturated, by boiling it in water, upon taking it out and

exposing it to the frosty air, the manner in which its particles scale away may be soon discovered.

When masons and bricklayers anticipate the setting in of frost, they invariably cover the new work with thick layers of straw, or matting, which being of non-conducting power, prevents the water in the cement or mortar from freezing and producing injury by its expansion.

It is a very common practice during Winter to surround water-pipes with thick hay-bands and straw-bands, or to cover them with stable-manure, and thus prevent the freezing of water, and the rupture of the pipes, which otherwise might ensue.

In a service-pipe a few feet beneath the surface of earth, water will seldom freeze unless the cold be extremely severe; but the part of the pipe which emerges from underground into the open air, as in passing from the street-main across a kitchen area; being thus exposed, the metal, by its good conducting power, will soon chill the water, and cause its own rupture; hence such part of the service-pipe either requires to be bound round with hay, straw, or other non-conducting material, to prevent freezing; or if the tap at the extremity of the pipe in the house be left partly open, the water, instead of remaining stagnant, and thus becoming frozen, will constantly flow, and oppose in a great measure the cooling power of the surrounding air.

In conducting the experiment regarding the congelation of water at page 298, the thin flask does not generally break when ice forms, because the neck being open, admits of the expansion; if a considerable portion of water freeze in this, and particularly if it gradually become narrow towards the mouth, the ice acts as a solid

plug to the water beneath, opposes its expansion upwards; therefore it is exerted in all directions around, and the flask is certainly broken; hence the necessity of applying the freezing mixture more around its bulb than its neck.

In the experiment with the "Cryophorus," at page 135, the instrument should be removed from the freezing mixture the moment after the ice has formed upon the surface of the water in the upper bulb; for if this be not perfectly spherical, the farther congelation of the water will generally break it by the expansion that we have been considering.

During the natural cold of Winter, when a glass "carafe" containing water breaks, generally speaking this happens if it be nearly filled with water, the freezing of that in the neck, acting as a barrier against the subsequent expansion of the portion of the bulb, when it freezes; but it sometimes happens that the glass escapes fracture, because the cold air, like the freezing mixture simultaneously enveloping it upon all sides, quickly reduces the whole temperature of the water to the freezing point, and the open mouth admits of the total expansion; or in other words, the ice will rise towards it in preference to exerting pressure upon the interior of the bulb; and again, if the "carafe" be only half full of water, its fracture seldom ensues, because there is plenty of room for expansion.

As in the experiment at page 207, we obtained a heating focus, by allowing the solar rays to fall upon liquid water, so shall we be enabled to obtain a like result with solid water; or, in other words, we can form a "burning lens" of ice.

Obtain a hemispherical mould of tin-plate, in fact a

bowl about eight or nine inches in diameter; place it to stand either upon a shovel full of hot sand, or upon the rim of a saucepan containing boiling water; then select a block of the most transparent ice that can be obtained, considerably larger than the bowl, and with a hammer chip away the solid angles of the block, so that it will just enter the bowl.

Of course the thawing of the ice will immediately commence, and it must be suffered to proceed until it has completely taken the hemispherical shape of the bowl; the block of ice must then be removed, and placed with its hemispherical part upwards, so that its base may stand upon a flat tin-plate, heated either by sand or water, as directed; the object now being to thaw the excess of base away, exactly level with the zone or circumference of the hemisphere; thus a "plano-convex lens" is obtained.

During the process of its formation, the operator may protect his hands from being numbed, by a thick pair of woolen gloves, and now still wearing these, carry the "ice-lens," and present its plane surface to the rays of the sun, at an open window, upon the sill of which is placed a piece of German tinder; move the lens about, at the distance of a few inches from this, and at length it will kindle; thus proving that the solar rays have been collected to a focus, and have lost no heat in their passage through the cold ice at 32 degrees.

Thus even in the Arctic regions, the rays of the sun have been collected by a lens of ice, in sufficient intensity to kindle gunpowder; in this country ice can always be obtained, and the experiment can be made during Spring, Summer, Autumn, and Winter.

Let us now direct our attention to other properties of solid water or ice.

The antiseptic power of ice is extraordinary, as the following remarkable natural example will prove: in the year 1803, at Yakoust, on the banks of the river Lena, in Siberia, the body of a mammoth slowly appeared from a mountain of ice in which it had been entombed and preserved from decay, according to all probability, from the time of the Deluge; the animal was sixteen feet in length, nine feet in height, and the flesh was in such excellent preservation, that not only did the bears and wolves devour it with eagerness, but the inhabitants of the district actually cut it up as food for their dogs.

Knowledge of this antiseptic power of ice is of great importance to us for the artificial preservation of animal food; such provision packed in ice will not undergo decomposition, because the water that it naturally contains as a leading proximate constituent, is rendered solid or frozen by the low temperature; and in such state, although still consisting of Oxygen and Hydrogen, it is incapable of promoting those changes or new arrangements of the ultimate elements of organic matter which are called putrefactive, as it is capable of doing in the liquid form.

Such frozen provision, if very slowly thawed, and immediately submitted to culinary operations, becomes wholesome food; if not, it rapidly putrefies, as it would in a recent state.

During the Winter in Russia, large and beautifully transparent blocks of ice are quarried from the surface of the frozen Neva, and stored up in cellars for the preservation of food; oxen and sheep are slaughtered, dismem-

bered, and allowed to freeze; the joints are afterwards packed in casks and sent to market; and although so hard as to require an axe to break them, the flesh softens by the thawing of the ice when immersed in cold water, and is fit for cooking.

Large quantities of salmon are shipped from Scotland packed in boxes with ice; indeed so important are its antiseptic powers, that of late years it has been imported from some of the lakes of North America; the chief employment of ice is by fish-merchants, for the preservation of their stock during the heat of Summer, because the animal fibre of fish is exceedingly prone to putrefy, by a very moderate elevation of natural temperature.

Confectioners, likewise, employ large quantities of ice for obtaining a sufficiently low temperature for making ice-creams, water-ices and other luxuries of the table, which are so grateful during the heat of Summer; and the collection of ice for all the above purposes affords active employment for many poor yet industrious persons, during the chill season of Winter.

Accordingly, upon the first intelligence that ponds are frozen over in the vicinity of London, folks who are stirring at daybreak may see parties of men and boys, proceeding with crow-bars, forks, rakes, poles, ropes and nets; in carts, wagons, and vans of every grade and denomination, in search of ice; a luxury to the rich, but a treasure to the poor; as by its collection, although a chilling, comfortless, and hazardous task, they earn a small pittance, which carefully expended upon the necessaries of life, will enable them to keep distress and famine from their cheerless abodes, for a short time at least, during the Winter that brings no festivity within their walls.

The ice thus collected is carted to the shops of fishmongers and confectioners, and received in their "ice-houses;" the construction of these receptacles for the preservation of the ice, throughout the Four Seasons, depends upon strictly scientific principles, and therefore demands a general description in this inquiry.

The sole object is to prevent the accession of heat to the ice, and therefore an "ice-house," or "ice-well," is generally formed at a considerable depth in the non-conducting earth, especially in the metropolis, where the surface is of such great value.

To construct an "ice-house," or, more correctly speaking, an "ice-well," a cavity is dug in the earth, in the shape of an inverted cone, and then built around with thick brick-work, like a well as shown in the accompanying sectional engraving.

Fig. 61.

At the bottom of the cone, a cart-wheel is laid flat, to serve as a grating, and immediately beneath this, proceeds a small brick drain, sloping gradually towards the main sewer or larger street drain.

About the middle of the small drain, as shown above, a small tank is placed, and a large flat paving tile, or slab of stone, descends from the upper part of the course

of brick-work constituting the small drain, to within a few inches of the bottom of the small tank, and this is half full of water.

The upper part of the cone is covered with a dome of brick-work, in the centre of which is an aperture, of any size most conveniently suited to the whole structure; and the horizontal part of the engraving, which proceeds from the white space on the left hand, denotes a brick-work passage, having two or three doors, by which access can be gained to the interior of the "ice-well;" this is charged with ice, as follows.

The aperture in the dome of the well is opened, as also the doors of the passage, and a truss of clean straw unbound and thrown down evenly upon the cart wheel; the cart loads of ice are then emptied upon the street pavement, and the ice is rapidly broken by clubs and mallets, into fragments small enough to pass through the aperture in the dome; these fragments are rapidly shoveled down, and when a sufficient quantity has thus fallen, one or two men, according to the size of the well, descend, and beat the ice firmly together with heavy wooden rammers, something like pavers' rammers; more ice is then shoveled down and beaten; and so on, until the well is perfectly and compactly filled; the workmen then pass out through the side door.

The aperture of the dome is then accurately closed by a slab of stone, which rests upon a ledge, formed for its reception; the shaft above this is several feet in extent; and its top, or mouth, is covered with another slab of stone, level with the pavement; thus, a considerable column of air is closely imprisoned or rendered stagnant, between the upper and lower slab; and this air,

by its non-conducting power, cuts off the access of heat to the dome of the ice-well.

The door in the brick-work of the ice-well is then closed, and the space between it and the next door, closely filled in with straw; this second door is then closed, and the space between it and the third door similarly filled, and so on until all are closed; the air, and the straw thus confined, cut off the access of heat to the ice in this direction; and thus the operation is finished.

Notwithstanding all these precautions, a portion of the ice will thaw; but the water from this thawing filters down through the remaining ice, through the straw, and between the spokes of the wheel into the small drain, and as it accumulates in the small tank, it overflows and passes to the sewer; at the same time, the slab of stone or paving tile, forms an effectual barrier against the admission of warm air from the sewer, so that by all these contrivances the ice is kept as perfectly as possible from obtaining heat, and the chief mass of it remains throughout the Summer.

A considerable thawing of the ice takes place when the doors are opened for obtaining such portions as may be required for use; on this account, and also of the great trouble that is required for removing the straw barriers, and shutting one door before another is opened, the proprietors of these "ice-wells" never open them more frequently than is absolutely necessary.

A small quantity of ice may be preserved, by placing it in a thick wooden box with a tight cover, and having four wooden clump-feet, about two inches high, to stand within another box, so that a space of two inches may intervene between its sides and cover; this

second box is then closed and provided with similar clump feet, and placed in a third, leaving the same intervening space; this may be placed in a fourth, and the last closely shut down; thus, by the non-conducting power of the wood, and of the intervening air, the ice will be prevented from thawing for a very considerable time; and so it may be by folding it in several yards of thick flannel.

During extremely cold weather, fish-ponds are so firmly frozen over, that the sheet of ice forms a perfect barrier against the access of the atmosphere to the yet liquid water beneath; and accordingly fishes would eventually perish, not by cold; but by the mephitic results of their own respiration, as at page 198, for solar light is feeble in Winter, and rendered yet more feeble by passing through the ice; the aquatic plants are not stimulated to exert their miraculous decomposing powers upon carbonic acid, it therefore accumulates, and proves fatal, unless we break holes through the ice; and then we immediately remark, how eagerly the fishes swim towards these, and directly breathe the newly admitted air; exactly the same as we ourselves, after long confinement in a close room, the air of which has been gradually vitiated by our own respiration, gladly advance to the window and throw up the sash, and thus admit the fresh air to relieve our faintness.

These holes in the ice require to be kept open from day to day, during the continuance of the frost, that the mephitic results of respiration may partly escape, or chiefly that the fishes may come to the surface and breathe; drawn there by necessity, they eagerly seize all baits that may be introduced by the fishermen, who are

aware of this fact, and accordingly turn it to profitable account.

In the case of very deep and extensive ponds naturally formed, we may generally, if not invariably remark, that they are not frozen over with one continuous sheet of ice, of uniform thickness and opacity; but in many parts circular patches, several feet in diameter, consisting of extremely fragile and transparent ice, are readily visible: and in others, even large circles of perfectly liquid water ripple in the winter blast; these phenomena announce the power and goodness of the Creator, and the miraculous provision which He has made for the protection of His wondrous works.

Although the cooling of the entire bulk of the water of the pond might have proceeded, by the intensity of the cold, to the degree required for the formation of one uniform sheet of ice, it must be remembered, that the pond thus deprived of receiving water from the clouds above, is not deprived of receiving water from the earth beneath; springs of water are constantly gushing through its bed, the temperature of this water is many degrees above that of the pond; it therefore swiftly rises, and coming into contact with the lower surface of the ice, commences its work of thawing those spots immediately above the spring from whence it ascended; these spots become thinner and thinner, so that fishes can easily burst a barrier so frail, and gain not only access of fresh air, but a more genial temperature than that of the main bulk of the surrounding water; or if they do not burst it, the winter wind will do so, and thus free them from imprisonment; or if neither force thus operates, the still ascending warm water will at length dissolve the icy barrier, within prescribed limits, and thus free

the creatures from the oppression under which they temporarily suffered.

But this is not the whole of the miraculous provision that is made by the Creator; He, for the fulfillment of a recondite purpose, may ordain the cold of Winter to be so protracted, and so intense, as to congeal the entire surface of the water into one sheet of ice, of uniform thickness, and thus prevent the access of the atmosphere; then He ordains the earth to cease the supply of water from its springs, and to exert its own property of attracting a portion of the water inhabited by the fishes; thus it is gradually drained from beneath the ice; which, yielding to the pressure of the superincumbent atmosphere, slowly bends to the utmost verge of its own elasticity; and at length suddenly cracks and admits the air.

The important fact to be borne in mind regarding the congelation of water, is this: when ice has formed, it matters not how much below 32 degrees the winds of Winter may descend; the liquid water, shielded by the ice, will maintain the invariable temperature of 40 degrees; persons who have accidentally broken through the ice, and become immersed in the water, generally remark, after escaping from such an unpleasant situation, "how much warmer the water felt than the air!" indeed, when the air is at or below zero, if we break a hole through the ice, the water at 40 degrees sends forth warm vapor, which immediately condenses in the cold air into minute crystals, and appears like white smoke.

An appearance of this kind is often seen hovering over marshes and brooks, and more particularly over the Greenland seas; it is there called "frost smoke," and in all cases is formed by the sudden congelation of aqueous

vapor; this phenomenon ceases when the surface of the water, and the incumbent air, become cooled to the same degree.

The vapor exhaled from our lungs is perfectly invisible on a hot Summer day, because the air is too warm for its condensation; if we breathe into a cold glass, it becomes dimmed by the condensation of the vapor, to the liquid state of water; and, upon an intensely cold Winter day, the vapor from our lungs becomes solidified into frost; occasionally, in Lapland, when the door of an apartment in which persons are assembled is suddenly opened, and a blast of cold air admitted, the watery vapor exhaled by their respiration, is instantly frozen into flakes.

In the early days of Winter, and at various times during its continuance, whilst the land may happen to be soft, the deep foot-prints of the husbandman, the deeper hoof-marks of cattle, and the ruts of heavy wheels, all become filled with the water of the next ensuing shower; this, from the strong contrast of the dark soil, glistens in the solar rays, like spots, patches, and threads of silver, and forms a pleasing feature of the wintry landscape.

If the shower be succeeded by a sharp frost, then all these little pools and streams are frozen; and being thus assimilated in whiteness and other physical characters, to the surrounding heavy "rime," they no longer strike the observer with their former bright silvery contrast; but reveal other beauties, if he condescend to the examination of things so lowly, and this he must do, if he wish to interpret Nature.

Within many of these foot-prints, hoof-marks, or wheel-ruts, the ice will be in the form of beautiful crystals,

crossing each other at angles of 60 and 120 degrees, thus forming an icy net-work, through the interstices of which the dark soil is seen; within others, again, the ice will be in the form of one perfect crystaline film; if either form be broken away, not the slightest trace of liquid water can be found; the cavities are all perfectly dry, and yet we must feel assured, that the delicate crystals or the fragile film, cannot contain the whole of the water in a solid form. Can the chemist account for this?

He can, as follows: in all these small cavities the water was cooled by the frosty air, though in some with more slowness than in others; accordingly, in the first case, crystals of ice formed at the sides, gradually accreted and individually shot across the water, and would have entirely covered its surface, had not another agent been simultaneously active; namely, the capillary attraction of the soil, which drew away or absorbed the water with rapidity superior to the cooling influence of the air; and thus the slightest subsidence of the water beneath the nascent, or newly-formed crystal, of course prevented its farther increase; this capillary attraction at length absorbed the whole of the water from such cavities, leaving a crystaline net-work of ice.

In the second case, crystals of ice formed with rapidity superior to the power of capillary attraction, and thus accreted into one entire sheet; but this, however thin it might be, prevented cold from penetrating to the water beneath, so that capillary attraction alone remained, silently, yet certainly active, and at length drew away the whole of this liquid water, leaving the film of ice suspended in the cavities, at the point of its formation.

These beautiful phenomena, for such they are, although of such common occurrence, are chiefly displayed upon

light calcareous soils, which are not very retentive of water, whilst in the foot-prints, hoof-marks, and wheel-ruts, on compact clayey soils, which are extremely retentive, the crystaline net-work seldom occurs, but only the icy film; and if this be broken, water appears beneath, as no rapid means for its escape was afforded by capillary attraction.

It is a favorite amusement with country boys, to let the air escape from these cavities, with a sharp sound, by suddenly thrusting the end of a stick through the film of ice, which is popularly called "cat's ice," probably in allusion to a smooth and fair appearance, upon which, generally, but little dependence can be placed.

Stagnant water, or water only subject to comparatively slight disturbances, universally presents the phenomenon of the formation of ice upon its surface, as now fully described; but in rapid and impetuous streams the formation of ice, when it occurs, is often very different, indeed exactly the reverse.

"In direct opposition, as it would seem, to the hitherto discovered laws of the propagation of heat, or cold, the ice in running water frequently begins to form at the bottom of the stream instead of the top; and this fact, while it is received with doubt by some, even among the scientific, is frequently attested by those whose business leads them to observe the phenomena connected with rivers."

"Millers, fishermen, and watermen find that the masses of ice with which many rivers are crowded in the winter season, rise from the bottom or bed of the stream; they say that they have seen them come up to the surface, and have also borne them up with their hooks; the under part of these masses of ice, they have found covered

with mud or encrusted with gravel, thus bearing plain marks of the ground on which the ice has rested; this form of solid water is popularly called "Ground-ice."

The formation of "Ground-ice" occurs only when the temperature of the whole bulk of the running waters is reduced to near 32 degrees, and that of the atmosphere is considerably below such point; it is preceded by a long continuance of a clear state of the sky; "but while forming under the continuance of a cloudless sky, its increase is impeded during the day; but when a densely clouded state of the sky occurs, and continues for twenty-four hours, the ice becomes detached from the bottom and floats down the stream."

Should the temperature of the air continue low, with a clouded sky, or become lower, the ground-ice is not renewed; but the river or rapid stream is speedily frozen over at its surface, in the usual manner.

The formation of "Ground-ice" only ensues, naturally, upon the rugged rocks and stones which form the beds of rapid streams; but when other solid objects, such as branches, and moss more especially, are artificially placed beneath these waters, the formation of the ice is copiously induced upon them; and this fact, combined with the previously stated aspect of the sky, furnishes a clue to the explanation of the phenomenon.

During our inquiry regarding the chemical phenomena of Spring, Summer, Autumn, and part of Winter, we have learned these facts; viz., that the temperature of the earth in this season, is greater than that of air; that radiant heat will pass through transparent media, without increasing their temperature; and that a cloudless sky is essential for radiation to ensue, and that it will ensue

with the greatest rapidity from rough surfaces; let us now venture upon the application of these facts to the phenomenon of "ground-ice."

The beds of the rivers or streams already mentioned, consist of rugged rocks and stones; these contain a certain degree of heat, and part with it, not by conduction, not by convection to the water, but by direct radiation through it to the cloudless sky; thus losing heat, they quickly cool the water in their immediate contact, and suddenly freeze it in films upon their surfaces; which films remain so long as radiation and the cloudless sky continue, but radiation ceases when clouds appear.

The solid surfaces then communicate sensible heat to the ice, or the clouds may send forth radiant heat downwards through the water to the ice; which, unlike common ice, is not smooth and glassy, but rough and porous; therefore capable of converting radiant into sensible heat, in a degree sufficient to cause thawing to take place; and therefore the detachment of part of the ice from the solid rocks and stones, and its floating upon the surface of the water; it there opposes all further radiation from below, and by actual contact, cools the water until a perfect sheet of ice is formed as usual.

Let us now turn to the contemplation and investigation of another beautiful attribute of Winter, that displays the wisdom and power of God:

"Great things doeth He which we cannot comprehend; for He saith to the snow, be thou on the earth."

"By his commandment he maketh the snow to fall apace; as birds flying he scattereth the snow; and the falling down thereof is as the lighting of grasshoppers,

the eye marveleth at the beauty of the whiteness thereof; and the heart is astonished at the raining of it."

Fig. 62.

Snow, thus eloquently and impressively described, very probably depends for its formation upon the gradual congelation of watery vapor in clouds amid the higher and colder regions of the air, where its capacity for heat is increased by expansion; the water thus becoming solidified, loses the support of the air, and the newly-formed crystaline snow-flakes, in obeying the attraction of gravitation, descend, and cover the earth with a mantle of spotless white.

This perfectly conceals the lowly remnants of vegetation from our sight, but we have reason to be grateful for its presence; the chemist discovers that snow is solid water in loosely compacted crystaline flakes, the beautiful form of which may be readily determined by catching them on a piece of black cloth, or on the top of a black hat, and immediately examining them with a high magnifier; they will be found to present the regular figures as shown in the engraving; and these may be regarded as the framework or skeleton of the solid six-sided prism into which water is more compactly frozen to constitute hail.

Like more massive ice, snow is a bad conductor of cold; it therefore protects seeds, bulbs and roots from the chilling winds that sweep over its surface, as effectually as the shield of ice protects the beings of the wave; in fact, vegetable productions are thus preserved from intense cold by snow flakes, as they would be by a fleece of wool.

Thus in the beautiful and impressive language of Scripture, "He giveth snow like wool."

This passage refers to the similarity between flakes of snow and fleeces of wool, in whiteness and lightness; and also to their similarity in power of preserving warmth around the bodies which they shield and clothe.

Snow is a great preservative against the effects of cold; wheat will continue growing beneath deep snow, whilst every blade would be killed by hard frost without snow; —beneath the surface the temperature of snow is very little colder than 32 degrees, whilst the air above is frequently 20 or 15 degrees.

If a piece of ground be left covered with snow, and another contiguous piece of ground be swept clean, after a day or two, upon digging both it will be found that the frost has penetrated very considerably below the surface of the piece unprotected by the snow; indeed it is recorded, in illustration of this protecting power of snow, that in "Holland, during the cold winter of 1776, the surface of the earth was frozen to the depth of twenty-one inches on a spot of garden ground, kept free from snow, but only to nine inches on an adjacent spot, covered with four inches of snow."

"In the northern regions, snow lying twelve feet deep during Winter, preserves the vegetables which are de-

stined to adorn the Summer, although the cold may be many degrees below zero."

The Esquimaux have learnt to convert snow into building materials, by which means they can raise a dwelling for their families in a few hours; a dwelling which, from the purity of the material of which it is composed, the elegance of its construction, and the translucency of its walls, gives it an appearance superior to a marble building.

Having selected a spot where the snow is sufficiently compact, they commence by tracing out a circle of from eight to fifteen feet in diameter, proportioned to the number of occupants the hut is to contain.

They then prepare a number of oblong slabs of snow, of six or seven inches thick, and about two feet in length, which are tenacious enough to admit of being moved without breaking, or even losing the sharpness of their angles.

These slabs, which have a slight degree of curvature corresponding with the circular foundation, are piled upon each other exactly like courses of hewn stone, and care is taken to make them fit closely to each other, by running a knife adroitly along the under part and sides, and to cut them so as to give the wall a slight inclination inwards.

Tier after tier is thus laid on by one man standing within the wall, who is supplied with material by one or more assistants from without.

But for the better convenience of transmitting this supply to the workman, when the wall has attained a height of five or six feet, a hole is cut on the south side close to the ground.

Thus they continue laboring till they have brought the

sides nearly to meet in a perfect and well-constructed dome, sometimes nine or ten feet high in the center; and this they take particular care in finishing, by fitting the last block or key-stone very nicely in the center, dropping it into its place from the outside, though it is still done by the man within; the people outside are in the mean time occupied in throwing up snow with the snow-shovel, and in stuffing in little wedges of snow where holes have been accidentally left.

The builder next proceeds to let himself out, by enlarging the hole on the south side into the form of a Gothic arch, intended as a doorway, three feet high, and two feet and a half wide at the bottom; communicating with which he constructs two passages, each from ten to twelve feet long, and from four to five feet in height, the lowest being that next the hut.

The roofs of these passages are sometimes arched, but more generally made flat by slabs laid on horizontally; in first digging the snow for building the hut, the workmen take it principally from the part where the passages are to be made, which purposely brings the floor of the latter considerably lower than that of the hut, but in no part do they dig till the bare ground appears.

The work just described completes the walls of a hut, if a single apartment only be required; if several families are to reside under one roof, the passages are made common to all, and the first apartment, in that case made smaller, forms a kind of ante-chamber, from which the entrance is through an arched doorway, five feet high, into the inhabited apartments; when there are three of these, which is generally the case, the whole building, with its adjacent passages, forms a tolerably regular cross.

For the admission of light into the huts, a round hole

is cut on one side of the roof of each apartment, and a circular plate of fresh-water ice, three or four inches thick, and two feet in diameter, let into it. The light is soft and pleasant, like that transmitted through ground glass, and is quite sufficient for every purpose; if fresh-water ice be not within reach, melted snow is poured into a vessel, and thus frozen into a transparent plate.

When after some time these edifices become surrounded by drift, it is only by the windows that they can be recognized as human habitations, and but for them, one might walk completely over them without suspecting the little hive of human beings that is comfortably established below.

The next thing to be done is to raise a bank of snow two feet six inches high, all round the interior of each apartment, except on the side next the door; this bank, which is neatly squared off, forms their beds and fire-place, the former occupying the sides, and the latter the end opposite the door; the passage left open up to the fire-place is between three and four feet wide.

The beds are arranged by first covering the snow with a quantity of small stones, over which are laid their paddles, tent-poles, and some blades of whalebone; above these they place a number of little pieces of net-work, made of thin slips of whalebone, and lastly a quantity of twigs of birch; their deer-skins, which are very numerous, can now be spread without risk of their touching the snow; and such a bed is capable of affording not merely comfort, but luxurious repose, in spite of the rigor of the climate.

With the lamps lighted, and the hut full of people and dogs, a thermometer placed on the net over the fire indicates a temperature of 38 degrees; when removed

two or three feet from this situation, it falls to 32 degrees; and placed close to the wall, stands at 23 degrees; the temperature of the open air at the time being 25 degrees below zero. A greater degree of warmth than this produces extreme inconvenience by the dropping from the roofs. This they endeavor to obviate by applying a little piece of snow to the place from which the drop proceeds; and this adhering, is for a short time an effectual remedy; but for several weeks in the Spring, when the weather is too warm for these edifices, and still too cold for tents, they suffer much on this account.

The interior appearance of these habitations is rendered more beautiful when they are situated on the ice, which, being cleared of the snow, presents a flooring of that splendid blue, which is perhaps one of the richest colors in Nature.

As the Spring advances, the snow walls melt and freeze alternately, forming innumerable icicles, which reflect the light like radiant diamonds; although this is very beautiful, it is a source of great trouble to the poor inhabitants, whose lungs become affected from repeated colds and coughs; for this reason, although the houses are formed of snow, coolness is the object always kept in view; and from the inexhaustible building materials always at hand, but little time and labor are required to effect any alterations or additions that may be requisite to effect the purpose.

Equal in beauty to the snow-houses are those constructed of fresh-water ice; when this material is employed, it is collected in large transparent slabs, which are arranged in somewhat an octagonal form, and plastered together with snow; the roofs of some are formed

of walrus skins, and others have the regular dome-tops of snow; these dwellings are so transparent, that even at some paces distance it is possible to distinguish those who stand within them, yet they are so completely air-tight as to be perfectly warm; a passage of the same pure material forms the entry to the hut.

The "red-snow" which is sometimes found in the Arctic regions, seems to derive its color from the presence of oxide of iron, in a state of extremely minute division, and a resinous vegetable principle of an orange-red color, belonging apparently to some lichen, of which too the iron may form one of the immediate principles; the coloring matter penetrates to various depths, and appears in the form of globules, varying from one thousandth to one three-thousandth part of an inch in diameter.

In Italy, snow is collected with as much assiduity as ice in England; the country surrounding the city of Naples is too flat and too warm to allow snow to remain on the ground in sufficient quantity to be collected; but the chain of the Appenines, traversing Italy from north to south, furnishes an inexhaustible supply.

A few of the loftiest of these mountains have their summits above the line of perpetual congelation, as mentioned when investigating the capacity of air for heat at page 124; accordingly they are clothed with snow throughout all the changes of the Four Seasons; but in the greater part of the range below the line of perpetual congelation, the snow of Winter melts about the month of May.

The Neapolitans excavate deep pits or wells on the sides of the mountains, or select any natural caves which may be found; and into these they throw, during the

winter season, thick pure layers of snow, collected from the mountains; each layer is pressed firmly before another is added, and thus the pits, wells, or caves, are completely filled; when this is done, a large quantity of straw, or of dried leaves, placed upon the upper layer of the snow, preserves it, as in the case of the ice in the "ice well," from the heating influence of the external air; and as the cavities are either artificially made, or selected from such as naturally exist on the northern aspect of the mountain, to avoid as much as possible the direct rays of the sun, and are moreover at a very great elevation; they maintain a very low temperature, even during the intense heat of summer. "Sometimes a fall of snow will take place in a valley, or in an inhabited spot at the side of a mountain; and in such case the peasants hasten out, and with an exuberance of joy at such a welcome occurrence, collect the snow, and place it in pits."

When the Summer arrives, the snow-diggers proceed to the pits, extract it, and bring it into the city, where it is sold at a regulated price, for the purpose of cooling water, and other beverages.

As an example of the bad conducting power of earthy substances, in the form of porous dust and scoria, it may be mentioned that the shepherds, in the higher regions of Mount Etna, are accustomed to provide water for their flocks, by strewing a layer of volcanic sand a few inches thick over the snow; and this earthy matter effectually prevents the heat of the sun from penetrating; the snow is withdrawn, and allowed to thaw in its direct beams, and thus form water, better than none certainly, but not well fitted for the support of life, as it is unaërated.

The reflection of heat by white, and its absorption by

black surfaces, may be well illustrated in Winter, by remarking that the snow will remain for many hours without thawing in the sunshine; but if its surface be lightly covered with black mould, the thawing will rapidly commence, because in the one case the heat is reflected, and in the other it is absorbed.

If the pieces of cloth employed in the experiment at page 155 be spread upon snow, when the sun shines their different absorptive power, as regards solar heat, will be illustrated by the black piece and the darker pieces thawing more snow, and therefore sinking deeper than the white piece and the lighter pieces.

In England and Scotland, snow storms sometimes come on suddenly, accompanied by high winds, which drift it into heaps; and in these, sheep are particularly liable to be enclosed, and either smothered or starved to death; such accidents often happen in the mountainous districts of the north of England and in Scotland, where vast flocks of sheep are reared.

"These animals will, however, live a considerable time, though deeply buried in snow; they appear to fall into a half torpid state, and the shepherd finds a part of his flock living when he had supposed them all to be dead; in such cases, however, the sheep which survive are so much weakened, that they generally become diseased, and die in the Spring."

Throughout The Four Seasons, the Almighty likewise, "by His great power, maketh the clouds firm, and the hail-stones are broken small."

So far as the cause of hail can be discovered, it appears to depend upon the sudden congelation of raindrops in falling through a stratum of cold air. The hailstones thus formed are more dense and compact than

snow-flakes from vesicular vapor; they more promptly cleave through the air, and strike the earth with great violence.

Unlike snow, hail is frequent in Spring, Summer, and Autumn, from some recondite cause, and is dreaded by the husbandman, on account of the devastation that it produces upon growing crops; but these heavy showers of hail and rain are instrumental in tending to restore the electrical equilibrium between the earth and the air, after its disturbance by the long-continued heat of the season, as already mentioned when considering the phenomena of the thunder storm; thus we have reason to be grateful to Providence for "Fire, and hail, snow and vapors, stormy wind fulfilling His word." In Winter, again, "The hoar-frost also as salt, He poured upon the earth, and being congealed, it lieth on the top of sharp stakes;" this beautiful phenomenon appears to result from the condensation of watery vapor into exceedingly fine drops, and their subsequent slow congelation into solid particles more minute than those of snow flakes. These particles falling through the air, are received by leafless branches, evergreens, blades of grass, stakes, fences, roofs, and other natural and artificial solid objects, which act as points of support, or nuclei; around such they accrete like crystals of salt, and charm the eye with their beauty, their silvery whiteness.

But in our temperate climate, these delicate crystals of water only glitter for a brief time in the beams of the wintry sun; then liquefy and vaporize by its heat, and thus return again to the air.

The beautiful phenomenon of hoar-frost upon branches and leaves may be artificially imitated in the following arrangement. Procure a few drams of crystaline "ben-

zoic acid;" it is a peculiar acid obtained from "gum-benzoin," or more popularly "gum-Benjamin;" and even this will answer the purpose to some extent, if its pure acid cannot be obtained.

Clean the glass shade and plate that were employed in the experiment described at page 101, by washing them with water, and carefully drying them with a soft cloth; then place the plate to warm before the fire in the usual manner, and likewise a shallow tin dish or pan, about two inches in diameter, to become much hotter upon the top bar of the grate.

In the meantime, select a branch of "arbor-vitæ," that will easily pass into the glass shade; mould a lump of clay, and stick the end of the branch in this, to support it upright; take a crystal or two of the benzoic acid, and drop this substance into the hot tin; and if it quickly volatilize, the temperature is sufficiently high; if it do not the tin must remain longer, until the volatilization of another portion of the acid will rapidly ensue.

Fig. 63.

Heat two thick copper penny-pieces red hot; take them out with the tongs, and set them one upon the other in the middle of the hot dinner-plate; then set the heated tin upon the copper coins. Place the lump of clay, with

the branch of "arbor vitæ," to stand near them; quickly fill the tin with "benzoic acid," and cover the whole arrangement with the cold glass-shade.

The "benzoic acid" will immediately volatilize, and its vapor coming into contact with the branch, will be chilled by it, and condense upon it in the form of beautiful and delicate snow-white crystals, closely resembling hoar-frost. The preceding engraving shows the arrangement for this extremely pretty and instructive experiment.

It is called "Sublimation," from a Latin word signifying "high," or "exalted," and it may be chemically defined as the conversion of a solid into vapor by heat, and the subsequent conversion of that vapor into a solid by cold; but the change is merely physical, and not chemical, meaning that the "acid" undergoes no change of composition; thus if "gum benzoin" were employed, its pure volatile acid would sublime and condense on the branch, leaving the fixed matters of the gum below, and by such "sublimation" the pure acid with which our experiment is made, was originally obtained by the chemical operator.

In the laboratory of Nature, the process of "sublimation" is not discovered upon a scale so gigantic as that of "evaporation," for very few solid substances, unless artificially extracted from natural sources, are volatile to any great extent by the ordinary changes of temperature during the Four Seasons; but in the vicinity of those extraordinary mountains called "volcanoes," sublimation proceeds with regard to "brimstone," or sulphur; it is probably raised in vapor by the subterraneous heat of volcanic fire; and as this vapor is exhaled

through the cracks and fissures of the soil, it condenses by the cold air into transparent yellow crystals, and into opaque yellow amorphous masses; and these, collected by the industry of man, constitute all the supplies of "native sulphur" that are demanded for the production of sulphuric acid, and the manufacture of gunpowder,—the latter an invaluable agent for removing the solid rocks which oppose the "getting" of mineral treasures, but unfortunately too frequently employed as a frightful agent for the slaughter of thousands of our fellow men.

The tremendous and destructive effects of gunpowder are referable to the sudden and intense combination of the sulphur and charcoal with the oxygen of the nitrate of potash that the composition contains; and the consequent production and evolution of many thousand times the bulk of the charge of powder, of highly heated elastic gases, and vapors of great projectile force.

Returning to the experiment, from whence these remarks originated:—upon removing the branch of "arbor vitæ" thus beautifully encrusted with crystals resembling "hoar-frost," it must be observed that it cannot be kept exposed to the air, as the acid will gradually volatilize; but it may be preserved for a considerable time beneath a glass-shade, in a cold room; and in this situation, if the crystals ultimately drop off, they may be all collected and sublimed again upon the branch, as at first; or upon a bunch of red flowers, either natural or artificial.

It will then exhibit a very close resemblance to the beautiful phenomenon that took place on the twentieth of March of the present year; when the beautiful pink and crimson blossoms of almond trees were suddenly

covered with white and delicate crystaline flakes of snow.

At the same time vegetation was exceedingly forward; many trees had put forth leaves, and these exposing great surface for the reception of the snow flakes; the whole feature of the landscape was far more striking than it is ever presented upon leafless branches during the depth of Winter.

The chemist discovers that substances capable of assuming the crystaline form, will generally adhere to porous or rough surfaces in preference to such as are compact or polished; he accordingly introduces sticks and strings into various solutions of salts, and these act as nuclei for the accretion of crystals; the most familiar examples of this kind that can be presented, are crystals of "verdigris" on sticks, and of "sugar-candy" upon strings.

In Nature, the same fact is observable; for during the congelation of water, the crystals of ice form first upon the stones, grass or moss, at the borders of the pond or stream, and then gradually proceed across the surface.

During the last experiment, the crystals of "benzoic acid" were found to be more abundant upon the rugged branch of the "arbor vitæ" than upon the smooth interior of the glass shade; and in Nature the same thing happens, for the crystals of water or "hoar-frost" are found more plentifully deposited upon leafless branches, and grass plats, and upon stone pavements and gravel-walks; and these two latter surfaces may be perfectly free from "hoar-frost" whilst a few withered leaves, straws, or feathers, lying upon them, will be beautifully encrusted with such crystals.

The delicate and elegant frost-work, resembling trees and landscapes, which forms upon the inside of window panes, results from the congelation of the vapor of water contained in the air of the apartment; and the same beautiful appearance displays itself upon the glasses of a close carriage, from the congelation of the moisture exhaled by the lungs of its occupants.

Fig. 64.

The appearance of hoar frost upon a window-pane, may be artificially imitated by dissolving half an ounce of "Epsom salt," *i. e.*, sulphate of magnesia, in a wine-glass full of hot water, and then spreading this solution with a sponge evenly over the surface of the pane of glass; as it cools, so it will crystalize in very beautiful arborescent or tree-like forms; and by this simple proceeding, window panes are now very commonly "frosted," in preference to the more expensive and hazardous method of rendering them opaque by grinding.

Two winters ago, at day-break, the flag-stones of the foot pavement of London exhibited the most splendid example of this crystaline form of water; the crystals were arranged, interwoven, and interlaced, in an endless variety of the most delicate and intricate figures that it is possible for the imagination to conceive; a very slight thaw having occurred in the night, the film of

water was suddenly frozen, by the frost setting in at dawn.

Sometimes, during a severe frost, by an occult process in the vast laboratory of Nature, heavy showers of rain suddenly fall; the drops are immediately frozen, and then trees, hedgerows, eaves of houses, and other solid objects, present a most beautiful appearance; they are coated with ice and icicles which reflect and refract the sunbeams in a variety of gorgeous colors.

If the conflagration of a building happen during a severe frost, the water employed to quench the flames is frequently frozen as it dashes and trickles over the walls, and forms brilliant icicles pendent from the parapet, portico, balconies, and window-frames.

The formation of icicles depends upon the successive congelation of drops, or slender streams of water; and in Nature they sometimes accumulate so greatly upon trees, that the branches break beneath the load, and thus much damage ensues.

The vicissitudes of the Four Seasons are continually changing the physical state of water, yet never altering its actual composition; for if the chemist experiment upon equal weights of this compound, in its three physical states of liquid, solid, and vapor, he invariably educes from them all, Oxygen and Hydrogen in the definite weights already stated.

Leaving, for a time, the effect of natural and artificial cold upon water, let us briefly examine the habitudes of this wonderful liquid when subjected to the action of artificial heat, as in the familiar process of boiling.

Why should the heat be invariably applied beneath the vessel containing the water, and never upon the surface of the water? The answer to this apparently simple

question involves the greatest refinements of chemical science.

It has been already stated that water is a non-conductor of heat, and this fact has been experimentally proved in several cases: therefore, if heat were directly applied to its surface, the portions of water constituting such surface would soon become elevated, by mere heat of contact, to the boiling point; and this boiling film, having less specific gravity than that of the colder portions below, would float upon them; whilst they cannot derive heat from it on account of their non-conducting power.

For example, let the iron heater of the tea-urn be heated red hot, and then by means of its hook, held that its end may touch the surface of water contained in a large tall glass: the heat will instantly cause the surface to boil furiously, whilst the beneath water will remain cold: nay, even a piece of ice, tied to a heavy bullet and previously placed in the water at the bottom of the glass, will not thaw, although the surface of the water at a few inches above is in a state of full ebullition.

Then, if water were a conductor of heat, it should all fairly boil, when the heat is applied above, as we know that it does when applied below; the theory of its ebullition, in the latter case, is as follows:

The heat is conducted through the vessel, and thus expands the water that it first reaches; the portions thus expanded are of greater temperature and of less specific gravity than others above, they accordingly ascend,—the same as a lighter fluid through a heavier,—they impart heat to these portions by contact; and thus losing temperature, they gain specific gravity; they fall, again

acquire heat, and diminish in specific gravity; they again ascend, and thus by carrying heat, or by convection instead of conduction, ascending and descending or convective currents are established, until all portions of the water are equally heated to a degree at which it can no longer remain liquid; then vapor or steam simultaneously escapes from all portions, vaporization rapidly ensues, or, in plainer terms, the water boils.

The whole of the water can never boil when the heat is applied at its surface, because convection, or ascending and descending currents cannot be established; the heated film, that in the other case is a convective film, is in this a heated non-conducting film.

A very beautiful experiment regarding the ascent of heated water and the descent of cold, can be made without much trouble, by attending to the following directions:

First, boil about two gallons of clean rain-water, in a clean tin saucepan for about an hour, then remove the vessel from the fire, cover it closely and allow the water to cool down to common temperatures.

Select a piece of glass-tube four feet long, about the twentieth of an inch thick, having a bore half an inch in diameter, and perfectly clean; if not so, it can be cleaned by passing a long string with a little cotton fastened to one end, several times through the tube.

Place a hand near each extremity of the tube, and thus hold it horizontally, that its centre may be at a distance of four or five inches above the heated air ascending from a large argand gas-burner, or above that of a bright charcoal fire in a small chafing dish or brazier; turn the tube round and round between the hands, that it may conduct the heat, or warm gradually at its center,

then continuing to turn, bring it lower and lower, or nearer the source of heat, and let it become fairly red-hot for about four or five inches; the hands will soon detect that it is soft and yielding, and by gently drawing them together in the same manner, as for bending a cane, the glass tube, or "cane" as it is technically called, will bend from its original straight form, and by still keeping this yielding portion in the heat, and still gently drawing the hands together, the tube will assume the form of a "syphon," having its limbs parallel to each other, though about four inches apart, and, like a syphon, one of these limbs should be about four inches longer than the other: this is managed by heating the tube originally a little beyond its true center; if, however, they should be of equal length, the matter can be remedied, of which hereafter.

Having wrought the tube into this shape, place its open ends in a box or jar, that its bend may stand uppermost, and thus slowly cool in the air; and when it is sufficiently cold to handle, it must be removed, and again heated in the following manner.

Hold the tube horizontally that about four inches of its longest end may become red-hot and soft, then by gently pressing against this with a sound piece of charcoal, or a stick of deeply charred wood, form it into a bend, exactly parallel with the first, though not quite so large; and this being done, place the first bend to stand in the box or jar, that the second may now cool.

When it is cold, remove the tube and place it flat upon the table, and very probably the straight limb of the tube will now appear the longest; if such be the case, take a sharp three-edged file, and gently make a deep cut across this, then hold the red-hot heater of an

Italian iron on the cut for half a minute, and if the tube do not crack, remove the iron and touch the file mark with the wetted tip of the fore-finger; this sudden cold will cause it to fly across, and by a very gentle pull, a piece will be thus cut off, and the limbs of the syphon will bear the same proportion to each other as shown in the annexed engraving.

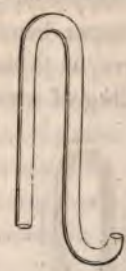

Fig. 65.

Select a thin earthenware basin, large enough to admit the two ends of the syphon, when placed in it with its large bend uppermost; then remove it, and fill the basin with a portion of the boiled rain-water, and stain this deeply with the well-known dye called "Saxon blue;" this being done, select a very shallow pan that will hold the syphon when laid flat within it; pour the remaining uncolored boiled rain-water into this, in order that the syphon may be perfectly filled, and every bubble of air excluded.

Then place a finger of each hand beneath the water, and close each end of the syphon; thus lift it, and when both ends are fairly immersed beneath the surface of the colored water in the basin, remove the fingers, and the syphon will remain full on account of atmospheric pres-

sure, as in the case of the "bird-fountain" and the "carafe" at page 201.

The basin thus containing the syphon must be now placed upon a ring supported on three feet,—a small tripod,—and the syphon very gradually raised into a perpendicular direction, so that the orifice of its straight end may be half an inch below the surface of the colored water: it may be supported at this elevation by a string attached to its upper bend, and fastened to any convenient support above, as to the arm of a chandelier, suspended from the ceiling of a room.

Fig. 66.

Although the whole arrangement occupies much time in description, and even in its performance, it is worthy of both, on account of the instructive result that it will afford, the object being to prove that hot water is lighter, and therefore will ascend through cold water, which is heavier;—let the flame of a spirit lamp be applied to the bottom of the basin, in a line perpendicular with the straight end of the syphon; and in the course of a few minutes will be presented the phenomenon, of which we

are in search, and which is represented in the opposite engraving.

The colored water at the bottom of the basin becomes expanded by heat, and rises towards the colder surface; no portion of such ascending water can enter the bent end of the syphon, because its orifice points upwards, but a portion can enter the other, as its end is directed downwards; accordingly, the warm blue water will be observed gradually stealing up this tube, whilst its cold colorless water is gradually falling down the other; the warm blue water continues rising; one limb of the syphon now contains blue, the other colorless water;—the heat of the lamp continues; the blue water reaches the bend, passes over, becomes cooled, and descends through the colorless, to the colored in the basin, and thus both limbs of the syphon are filled with blue water, and the experiment in illustration of ascending and descending or convective currents is concluded.

It may here be remarked that the object of boiling the rain-water is to expel the air from it, for if this precaution were neglected the subsequent evolution of air-bubbles in the syphon would materially interfere with the successful result that is desired.

Thus in every case where heat is applied beneath the vessel containing water, that extraordinary liquid is elevated to its boiling point by convective currents: now let us inquire the degree of heat that is required for this phenomenon to ensue.

Plunge the bulb of a mercurial or "Brewing thermometer" into rain-water contained in a tin cup, then apply the flame of a spirit lamp, and as the water gains heat by convection, the mercury will gradually rise until the water boils, and then it will remain stationary about 180

degrees above the "freezing point," or as it is marked upon the scale 212 degrees; this is called the "boiling point of water."

Experimenting at different times with water in a state of ebullition, the chemist discovers that its boiling point is liable to much variation, being sometimes materially above, and at others below "212 degrees."

Searching for the cause of this variation, he detects the invisible though certain agency of the air, which, considered as an entire volume, though of constant weight, is liable to local variations in its density, chiefly by the agency of solar heat, and that it presses with greater weight upon the earth at some times than at others. When the pressure of the air is equal to that of fifteen pounds upon every square inch of surface opposed to its action, artificial heat can cause water to boil at 212° on earth at the level of the sea. If the pressure of the air increase, or if it diminish from this, which is conventionally termed its "standard pressure," the boiling point of water is elevated in the one case and depressed in the other, because in the former case, the heat has to oppose the pressure of the air, which is tending to preseve the water in a liquid state, and in the latter the heat has not so much pressure to contend with, but the rarity of the air rather aids its conversion of the water into vapor.

Further experimenting upon this curious and important phenomenon, the chemist discovers that at various heights and depths from the surface of the earth, water sustains an alteration in its boiling point dependent upon the rarity or density of the air; which, as already mentioned, decreases in weight as it ascends from the level earth. Accordingly upon the summit of a mountain 15,781 feet above the level of the sea, water will boil at 180 degrees,

instead of 212 degrees, as at the level of the sea:—a temperature inadequate for the preparation of food.

At the bottom of a mine 1,650 feet below the level of the sea, water will boil at 216 degrees, a temperature better suited for the preparation of food, by extracting all its soluble nutritious matters, than the ordinary boiling point upon the level earth, and very much better than that upon the mountain summit.

The freezing point of water is immutable, whatever variations may ensue in the pressure of the air, but the Almighty has ordained the boiling point of water to sustain changes in its temperature, and to be highest on the surface, or below the surface of the earth, where its utility is most required for man.

The chemist, therefore, when speaking of 212 degrees as the "boiling point of water," means that such is the thermometric temperature required for the vaporization of water by artificial heat, when the experiment is made with absolute water in a metallic vessel on the earth at the level of the sea, and when the atmospheric pressure is equal to fifteen pounds upon every square inch, or is at "mean pressure," which the "barometer" denotes when its column of mercury stands at thirty inches, and under such circumstances the thermometer is graduated.

The manner in which the boiling point of water is affected by diminution or increase of atmospheric pressure may be experimentally demonstrated by very simple means.

If a portion of water not sufficiently hot to scald the hand be poured into an air-glass and placed upon the plate of the air-pump, and covered with the receiver, as at page 171, upon exhausting the air, and thus freeing it from pressure, the water will boil as briskly as

though set over the flame of a lamp, thus artificially imitating the phenomenon that naturally ensues, when water is gently heated on the summit of a lofty mountain; but the boiling will stop if the action of the pump be suspended, because then it becomes subjected to the pressure of its own vapor which fills the receiver, and the amount of heat yet retained by the water is insufficient to raise it into further vapor against this pressure, which is exactly equivalent to that of the external atmosphere under which the water had ceased to boil before it was subjected to the experiment.

The action of greater pressure upon water actually boiling under that of the atmosphere may be proved by making the following arrangements: pour away the spirit of wine from the flask employed in the experiment at page 292; then wash the flask with water, drain it, and pour in about a quarter of a pint of rain-water; suspend the flask over the heated air of a gas flame, or let it be held by the fingers protected with a thick worsted glove, over the flame of a spirit-lamp, that the water may boil.

Select a bladder about the size of the flask, and after soaking it in water, cut off its neck, so that an aperture will be made large enough to admit the upper part of the glass tube that belongs to the cork, as used in the experiment with the flask at page 292; secure the neck of the bladder around the tube by tying it firmly with thread, and this being done, blow the bladder full of air.

When the water in the flask boils, insert the cork very quickly and firmly, and then compress the bladder, the boiling will instantly cease; allow the bladder to

expand, and the boiling will instantly recommence. Why?

Because the water was boiling at first at a temperature of 212 degrees under ordinary atmospheric pressure, but by compressing the bladder the pressure was suddenly increased, and the same degree of thermometric temperature was insufficient to create steam against this, thus closely imitating what happens in the depth of the mine; the heat would eventually increase and be superior to this pressure, the water would boil at a higher temperature as in the mine, but the experiment might be attended with danger by the bursting of the flask; when, on the other hand, the air in the bladder was allowed to expand, its pressure became the same as that of the external atmosphere, and the water retaining sufficient heat, formed steam equivalent to this, or in other words, it boiled at its usual temperature of 212 degrees.

As few liquids are alike in their specific gravities, so very few are alike in their boiling points, even when experimented upon at the level of the sea, and under the mean pressure of the atmosphere; thus the boiling point of "brine," or saturated solution of common salt, is 12 degrees above that of absolute water, or 224 degrees; the boiling point of ordinary spring-water is hardly one degree above that of absolute water, or 213 degrees; and it is found that in proportion as saline substances are dissolved in water, so does the boiling point become higher and higher, and this quite independent of fluctuation in atmospheric pressure.

Thus if pure water be boiling at 212 degrees, and the barometer standing at 30 inches, if common-salt be gradually added, as it dissolves so will the mercury in the

thermometer gradually rise, and at length become stationary at 224 degrees, when the water is saturated with the salt.

On the other hand, Alcohol and Ether have boiling points lower than that of water under like circumstances of pressure, the former boiling at 180, and the latter at 98 degrees; accordingly such liquids will boil vehemently in an exhausted receiver; but the experiment cannot be advised, as their vapors corrode or dissolve the oiled-silk valves of the pump, and quickly render a valuable instrument perfectly useless.

Knowledge of the fact regarding the difference between the boiling points of water and of alcohol, enables the chemist to separate them from each other; take, for example, the combination of these liquids, originally made in the experiment detailed at page 115; place it in the copper boiler of one of those small models of "stills" that are now so commonly sold; fix on the "still-head," insert its "beak" into the "worm-pipe," fill the worm-tub" with cold water; apply a lighted lamp beneath the "boiler," and place a small glass at the end of the "worm-pipe" that comes through the lower part of the "worm-tub."

The heat of the lamp will effect repulsion between the chemically combined liquids; the alcohol requiring the least heat for its ebullition, will first rise in vapor; this will condense in the cold worm-pipe, and trickle into the glass; and by receiving the drops from time to time upon a folded slip of blotting-paper, and holding this to a flame, the alcohol will kindle and burn with a very pale flame; at length the drops so received will not kindle; and this fact announces that all the alcohol has separated or distilled, and the drops now consist of water

that is boiling and distilling, therefore the process must be stopped, for the separation or analysis is effected, the alcohol being in the glass, the water remaining in the "boiler."

Pour the alcohol thus "rectified"—but not absolutely anhydrous—into a vial containing half its bulk of dry pearl-ash; shake it three or four times, then let it remain undisturbed; the pearl-ash, on account of its strong attraction for water, and its want of attraction for the alcohol, will abstract the former, and produce a solution upon which the latter will float on account of its small specific gravity: let this be decanted into the "boiler"—previously emptied and dried as also the "worm-pipe;"—add half an ounce of quick-lime; apply the gentle heat of the lamp; the lime will arrest or hold back any water that had escaped the pearl-ash, whilst the vapor of the alcohol will rise and condense into drops of "absolute" or pure alcohol.

The process of separating alcohol from water, or one liquid from another to a certain extent, by the mere application of heat, is extremely ancient, and is technically called "Distillation," from a Latin word signifying "to drop;" and it may be chemically defined as the conversion of a liquid into vapor by heat, and the subsequent conversion of that vapor into a liquid by cold; in this respect it differs from "Sublimation," but yet agrees with it in the fact of the change being merely physical and not chemical.

Thus the chemist is enabled to obtain pure water from brine, sea-water, or river water, the "absolute water distilling away from the saline and earthy matters that are not volatile at the same temperature; exactly as in

the last experiment, the "volatile" alcohol distilled away in the first place from the comparatively "fixed" water, and in the second from the more perfectly "fixed" lime.

The evaporation of water from the earth, and its subsequent fall in drops as showers, is a grand and important example of "distillation," proceeding in the vast laboratory of Nature.

Water has the invaluable property of invariably maintaining its chemical composition, however violently its physical form may be changed, by the artificial application of cold or heat to the state of solid ice or elastic steam; and if the latter be prevented in its escape from the water, by which it is generated, as by closing the vessels in which the experiment is made, the water rises far above its ordinary boiling point, and the steam, partaking of such increase of temperature, acquires an enormous elastic force, and hence is employed as the motive power of the steam-engine, a machine that is working wondrous and strange changes upon the physical, moral, and intellectual condition of mankind.

Constructed of astonishing accuracy and strength by the skill of modern engineers, we behold the condensing steam-engine "thrusting its giant arm amid the solid strata of the globe, excavating spacious galleries and mines, drawing forth the rivers which inundate and encumber them; tearing from the rock the boundless mineral wealth therein deposited by nature," hurling it to the surface, assisting in its reduction to the metallic state, and its subsequent manufacture into countless forms for the use of the arts.

"We see the steam-engine uniting power with delicacy:—we see it twisting, with equal success, the im-

mense folds of cable,—and the gossamer filaments of delicate lace."

We see it as applied to the manufacture of paper, producing with celerity sheets of paper of the most even and perfect texture, and any number of miles in length that may be required! Then, again, as applied to the printing-machine, by which we are rapidly supplied with cheap and beautiful publications.

We observe the application of the same agent to the reduction of iron from the ore; and its formation into the endless variety of states demanded by the civil engineer, for satisfying the calls of the wealthy and enterprising capitalists of this nation.

In one year alone, the steam-engine produced one million eight thousand tons of cast and wrought iron, the value of which amounted to nearly seven millions sterling, furnishing employment to forty thousand men, and consuming three million tons of coal.

Its application to calico-printing has summoned into activity the skill of two hundred and thirty thousand workmen, who in one year produced by its agency eight millions and a half pieces of calico, and they received for their labor capital to the amount of two millions four hundred thousand pounds sterling.

Lastly we see the steam engine applied to ships, the perfection of steam navigation,—the speed with which the beautiful machinery of the condensing engine propels a magnificent vessel over the waters of the wide Atlantic, causing its arrival on the shores of the New World in less time than was formerly required to sail from one extremity of the United kingdom to the other.

The Almighty was pleased to prolong the life of the great, good, and amiable philosopher, who, after long

and laborious study, perfected this mighty invention, to the advanced age of fourscore years and four; and then "expressing his gratitude to Providence for that length of days and exemption from infirmity which rendered the evening of his life cheerful and serene, he yielded up his soul in the calmest tranquillity, and passed without pang or struggle from the bosom of his family to that of his God.

The wondrous invention bequeathed to us his countrymen is a monument upon which his name is engraven, and never can it be effaced or forgotten;—better far than the gorgeous monument of sculptured marble, and moulded bronze, which time crumbles or corrodes into dust, and ultimately mingles with its parent earth.

"The true end of all science is to enrich human life with useful arts and inventions." What can be a more magnificent illustration of this precept than the invention just alluded to, or its modification into the high pressure locomotive engine and its present employment upon the iron roads, which ramify throughout the empire, drawing in its giant train with incredible velocity sumptuous carriages laden with thronging hundreds of passengers?

The steam engine, in all its details and bearings, forms a most important and interesting subject for our reflection.

But to return more immediately to the chemistry of the water, whose vapor is the motive power of every modification of this miracle of art.

The chemist discovers, upon examining the host of metals enumerated at page 19, that some of them have more attraction for oxygen than others; indeed so intense, that they cannot be exposed to the air, or any other mix-

ture or compound containing that element, without immediately tarnishing, rusting, or oxidizing.

He farther discovers, that a change so sudden, regarding the physical and chemical characters of such metals and oxygen, develops the imponderable agency of Electricity in its utmost artificial degree of power; and this conducted by wires of the least oxidizable metals, into water, immediately causes repulsion between its elements, or resolves it into Oxygen and Hydrogen, in the above definite proportions of weight and measure; this extraordinary experiment is technically called the "electrolysis of water."

It furnishes the only method that is known of simultaneously eliciting both the elements of water; and as the manipulations requisite for the success of the experiment can be learned from the generality of many popular works on the rudiments of Electricity and Chemistry, reference is made to these, if such information be desired; whilst we can proceed with a few examples of the evolution of Hydrogen from the decomposition of water, that are not so generally known, yet most intimately connected with this inquiry regarding the principal chemical phenomena of the Four Seasons.

Fill a Florence flask with rain-water, and invert it into a basin containing water, exactly after the method described for the "carafe" at page 201; obtain three or four globules, about the size of peas, of the metal Sodium; these will be presented, by the vendor, in a small vial, containing a portion of colorless, or light yellow-colored liquid; it is a native compound of Carbon and Hydrogen, called "naphtha," from an oriental word, signifying to "pour out or to exude," as this liquid does

from the soil on the banks of the Caspian Sea; and as "naphtha" contains no oxygen, it forms an invaluable liquid coating or medium for preventing the globules of sodium from combining with oxygen until the moment that such effect is willed by the operator.

Let one of the globules of the metal be taken out on the point of a knife, then placed on blotting paper, and cut into four pieces; in doing this, its metallic splendor will appear for an instant, but then will tarnish or become dull white, on account of its combining superficially with oxygen from the air, and forming Oxide of sodium or Soda.

As such, combined with carbonic acid, it is found in ancient "nitre," or "natron," constituting native carbonate of soda; and as such again it is obtained by the combustion of marine plants, and is found in their ashes, the same as oxide of potassium or potash is obtained by the combustion of wood, and is found in the resulting ashes as carbonate of potash, which engaged so much of our attention at page 276.

From the ashes of marine plants Sodium is ultimately obtained, in a manner similar to potassium from wood ashes; and thus the chemist is presented with the extraordinary fact, that the plants of the ocean and of the earth contain each a metal brilliant as silver, but having the two strongest attractions for oxygen of all simple or compound matters: let us take advantage of this fact in the case of Sodium, for decomposing a portion of the water in the Florence flask.

The globule being cut into four pieces, press each of these upon the blotting-paper to absorb the naphtha; then fold each separately, yet tightly, in a very small piece of dry thin glazed paper, stained of a bright yel-

low, with tincture of turmeric root; grasp the lower part of the bulb of the flask with one hand, and thus lift it so that its neck may be about an inch beneath the surface of the water, near one side of the glass in which it is inverted; then take one of the packets of sodium between the finger and thumb of the other hand; plunge it quickly beneath the water, and when directly beneath the mouth of the flask, relax hold of the packet, and although containing a solid metal, yet like solid ice it will rise to the water at the top of the flask, because it is lighter than water, its actual specific gravity being nearly the same as that of ice, viz., Water, S. G. = 1.000; Ice, S. G. = 0.940; Sodium, S. G.=934.

This is another extraordinary fact; but one yet more extraordinary will soon present itself: as the water creeps through the paper by capillary attraction, and comes into direct contact with the sodium, myriads of minute air bubbles will exude from the pores and folds of the paper, with a rapidity increasing every moment, and at last a globule of the metal will burst forth, like a bead of silver; but it will float upon the water, whilst myriads of air bubbles will surround it on all sides; the globules will diminish in size, and when very minute, and just before it vanishes, it may very probably become red-hot; the air bubbles coalesce into one large bubble, as did those of oxygen, evolved by the "conferva" in the "carafe" at page 203.

In this experiment, as indeed in all others where intensely active agents are employed, the face of the operator should not be held directly above, or very near the vessels or apparatus, lest an explosion happen; but suppose the experiment successfully performed thus far, let the remaining packets of sodium be similarly intro-

pound, at the instant of its formation, is in the state of Two volumes of Vapor, this, upon cooling, sustains a most excessive condensation into $\frac{1}{1800}$th part, to form liquid water!

To impress upon the mind of the young student this extraordinary fact regarding the enormous volume of gaseous elements that are included in a drop of water, let 845 peas, all similar in size, represent the One Volume of Oxygen, and 1690 similar peas represent the Two Volumes of Hydrogen; then 1690 more peas would represent the Two volumes of the Vapor of Water, which the Three Volumes form, and a single pea will represent the drop of water that results from its condensation.

It is some little trouble to count so many peas; but once accurately done, the three heaps may be preserved in three bottles, and are extremely useful for illustrating the fact at any future time.

Knowledge of the composition of Water is of great importance in chemistry, it enables philosophers to explain many phenomena that were formerly mysterious, and affords an excellent example of a compound differing in all its habitudes from those of its elements.

Thus, gradually, have we discovered the leading characters of Carbonic acid, Water in its three physical states, and the elements Oxygen and Hydrogen; one more experiment will enable us to discover the leading character of Nitrogen, and then our chain of inquiry will be complete.

Take a flask employed in the experiment with the sodium at page 373, wash and dry it thoroughly; this last operation is best effected by holding it near a fire, with its mouth downwards, until the bulb becomes very

hot, then inserting the nozzle of a pair of bellows to blow out the steam; when this is effected, place the flask upon a flannel and let it cool for an hour at least; this is essential.

Obtain a stick of Phosphorus about an inch long, shake it from the vial full of water in which it is kept, into a cup, then remove it from this by sticking the point of a knife into it, and press it with a dry cloth; gloves should be worn during this proceeding, and a large basin of water placed near, so that if the phosphorus spontaneously inflame, which it will do by moderate heat or friction, it may be extinguished by the affusion of water; and so may its flame upon the gloves, should such accident ensue; but suppose the phosphorus be successfully dried upon the cloth, and the flask perfectly cold, by means of the point of the knife, lift the phosphorus into the flask, cork it tightly, and then place the neck, thus corked, beneath the surface of water contained in a finger glass, as already directed, and leave it at rest for twenty-four hours.

During this time, the phosphorus will slowly combine with the oxygen of the air that the flask contains; and if the apartment be darkened at the outset of the experiment, the beautiful lambent light, like that of the glow-worm, attendant upon the slow combustion of the phosphorus, will be visible; when the time has expired, still keeping the neck of the flask under water, withdraw the cork, the phosphorus will fall into the finger glass, but water will rise from this a very considerable height into the neck, and even part of the bulb of the flask. Why is this? what is there in the flask to pull up the water? it only rose about half an inch in the experiment at page 65; then why this extreme rise?

In the experiment to which allusion is made, the flask contained air, and it being subjected to a slight compression by the weight of the water, a very little water only ascended; so that the volume of the air in the flask was very nearly of the same density as that of the external air; but heat being applied some of the air escaped, and upon subsequent cooling, water ascended to supply the place of such portion of expelled or abstracted air; ascended, like that in the flask from which the cork has just been withdrawn, but in this experiment there is more to be considered.

Fig. 67.

The atmosphere consists of about one volume of Oxygen, and four volumes of Nitrogen; and during the inclusion of the phosphorus in the flask, it has slowly combined with, or withdrawn the one volume of Oxygen, to form a few drops of Phosphorous acid; the air would have entered to supply this deficiency had not the neck of the flask been corked, and placed under water, to keep it air-tight; so that now less than the original volume of the air is in the flask, and upon removing the cork, the external atmosphere pressing upon the surface of the water in the finger glass, forces a portion of it

upwards to supply such deficiency, and at the same time to indicate its extent, the remaining aëriform matter is pure Nitrogen, for which phosphorus has no attraction under these circumstances; thus, the air is analyzed, its Oxygen or supporter of combustion being combined with the phosphorus, and its Nitrogen, or non-supporter of combustion, liberated.

Replace the cork, then lift the flask, place it on a ring, and introduce a lighted taper; the flame will be extinguished, as effectually as though it were plunged into water, and thus we obtain evidence of the leading character of Nitrogen.

Such are a few of the extraordinary phenomena regarding the properties of elementary and compound matter, that reward the investigations of the diligent student of the delightful science of chemistry; the pleasure derived from this department of knowledge, concerning the wonders of the Creation, is unceasing; and so varied that it never satiates the sense, at the same time it is far removed from the low gratifications of sense in another respect; while those hurt the health, debase the understanding, and corrupt the feelings, this elevates and refines our nature; teaching us, whilst contemplating the wonders by which we are surrounded, and which are so essential for our welfare, to acknowledge the Omnipotence of The Hand by which they were created, and are perpetually governed.

At this inclement season of the year, when the trees are bare, the streams fast bound in icy fetters, the sky obscured by tempests, and the chilling winds howling around our dwellings, we become fully sensible of the comforts of an "English fireside;" and the examination of the chemical phenomena that it likewise pre-

sents, will be found to bear most intimately upon much of our previous inquiry, regarding the habitudes of solids, liquids, and gases, with cold and heat.

The materials generally laid in a fire-grate are paper, wood, and coal; and there is much philosophy in this seemingly simple arrangement; for these substances are placed in the order of their combustibility, they are all closely allied in chemical composition, they differ materially in physical form; paper being fragile, wood tough, and coal brittle.

A lighted match applied to the paper, instantly causes its inflammation; this kindles the wood, which does not burn so rapidly on account of its greater aggregation, and therefore allows sufficient contact of its flame to excite the combustion of the more closely aggregated coal; this soon ensues, the fire burns well, the smoke and vapor swiftly ascending through the chimney.

At first sight there appears no reason why a fire might not be kindled as readily at the top of the grate as at the bottom, but daily experience shows us this cannot be done, and for a very simple reason, which may be illustrated as follows.

Fold a long strip of paper into the form of an ordinary "allumette," kindle one end of this, hold it horizontally, and the flame will immediately ascend powerfully from its upper side; and however it may be held, the flame will always ascend, and most rapidly when the paper is held with its kindled part pointing downwards; do these simple matters appertain to chemical philosophy? they do, and for the following reason.

The flame cannot burn without air, and as it chemically withdraws Oxygen from such portions of this wondrous medium as are in immediate contact with it,

this action mechanically disturbs the natural equilibrium of unchanged or fresh portions, at some distance around and below; these, accordingly, move swiftly onward and upward, to supply the deficiency occasioned by the flame; and it consisting of volatile matter, is urged by the force of such moving air, into a pointed or pyramidal form.

The dangerous and fatal accidents that have happened, more particularly to females, by their thin dresses catching fire, afford sad illustrations of the invariable ascent of flame.

In the case of dresses catching fire, persons generally are greatly alarmed and lose their presence of mind, and therefore run wildly to and fro, thus fanning the flames into their utmost intensity; the prudent plan is, to lie down upon the floor, and roll the hearth rug around the body to exclude the air, and thus extinguish the flames; or, if there be any bystanders at the time of the accident, the cloak of one or the coat of another, thrown around the body of the sufferer, will instantly quench the flames.

A simple experiment may serve to impress this useful fact upon the mind; spread a sheet of paper, flat upon a board, kindle the four corners of the paper, and observe how slow, how imperfect will be the combustion; and to what a small extent the flame will rise; because the air has only access to the upper part of the paper, and cannot enter below to urge the flame to its full pointed intensity of height; as it will do the instant that the sheet of paper is lifted upright, by taking hold of one corner with the tongs.

But in either case, the flame may be perfectly and

safely quenched, by spreading a thick cloth over it to prevent the access of air; it should be particularly borne in mind, that no common flame can burn without access of air; but now, to continue our investigation regarding the philosophy of applying such flame to the lower strata of fuel in the "fire grate."

It is a well-established fact, that all substances,—not even excepting water, after a certain degree is passed,—under the influence of heat increase their mass, bulk, or volume, and diminish in their specific gravity; they, accordingly, in the case of mobile liquids, gases, and vapors, have an immediate tendency to ascend through colder and heavier portions of their own nature, or in many cases of other liquids, gases, and vapors, of totally different nature; thus, if the hand be held some inches above a flame, great heat will be felt, for the products of combustion, namely, Watery vapor and Carbonic acid, are both intensely hot, both specifically lighter, and therefore ascending through the colder, heavier air; if the hand be held under the flame, little more than actual heat of radiation will be felt upon its palm, whilst its back will feel cold, by the fresh air ascending to supply the place of the escaping products of combustion.

Let the thermometer with its blackened bulb, employed in the experiment at page 152, be held some distance above, and then the same distance beneath a horizontal flame, and in the former position it will indicate a much greater temperature than in the latter.

The reason, then, of kindling the fuel in a grate at the lower bars, is that the flame may assume its pointed form, and ascend, with its own heated products; which, gradually drying and heating the wood, and it in turn the coals, induces their combustion; then all the products

ascend through the chimney, and emerging from it into the air, if it be calm will continue ascending for a considerable height as one unbroken column, whilst fresh air enters the room, to supply the fire, still urging the ascent of its flame and heated products.

If, on the other hand, the fuel were laid in an inverted order, the paper being uppermost, this upon being kindled would immediately obey the impulse of the air, and ascend in flame with such rapidity, that the wood, unless extremely thin, would be prevented from gaining sufficient heat to burn; and then in turn, it would pass away with rapidity, without kindling the solid coals.

In all ordinary cases of the employment of coals as fuel, a portion of carbon passes away unburnt, in the ascending draught of actual products of combustion; and this carbon constitutes the chief part of the black smoke, yet being highly heated, it generally floats for a considerable time in the air.

Remark the dense volumes of smoke that issue from the lofty stacks of steam-engines, breweries, and gas works; how far they travel, through the calm air, and do not appear to blend with it; the watery vapor and carbonic acid that they contain, do really blend and dissolve in the air, but the unburnt carbon, cannot do so, it therefore remains mechanically diffused for a considerable time, until it becomes so cooled as to fall in the form of "blacks."

On the other hand, remark the dense white cloud of steam that issues from a railway engine, with what force it ascends a considerable distance in the air, and then forms small clouds; but these immediately vanish and do not travel like the carbon of smoke, because they consist of nearly pure watery vapor, and chemically dis-

solve in the air without altering its transparency; the same as a lump of white sugar will dissolve in water, without altering its pellucid appearance.

Smoke, therefore, presents an example of the mechanical diffusion of a substance; and steam, an example of the chemical solution of a substance in the atmosphere; again the dust of Summer, and the snow flakes of Winter, floating in air, present examples of "diffusion;" and when they fall, of "precipitation" from such medium; but the solid dust can never return into the air save by its mechanical impulse; whilst the snow flakes, by first changing from their solid state to that of vapor, by the warmth of the air, chemically return into its vast and capacious volume.

Returning to the chemical phenomena presented by an ordinary fire, we find it a point of the utmost importance, that the products of combustion and the smoke should have free escape, and that it is absolutely necessary to admit as much air into the room as the flame consumes; if this be prevented, by nailing leather around the doors, or placing sand bags at their thresholds, or upon the window frames, the smoke, instead of ascending, will be forced into the room by a current of air descending from the chimney-pot, to supply the deficiency of that in the room.

The admission of cold or fresh air to the lower part of the fire, without occasioning the inconvenience of a draught, is one of the most difficult problems for practical solution that can be presented, and probably the simplest plan is to carry an open tube from the hearth into the external air; at all events, the fresh air should gain admission at or near the floor, and not at or near the ceiling of a room; the latter situation is the most suited

for its escape when heated and vitiated by the combustion of candles and gas, and the respiration of the inmates of the apartment.

The greater heat of the air near the ceiling of a room in comparison with that upon the floor, is directly felt by any person ascending a pair of steps: as for example, to reach a book from the highest shelf of a library; and a further proof of the tendency of heated air to ascend to the ceiling, is presented by the fact of its plaster appearing darker in some parts than in others, and for the following reason:

The heated air carries dust and fine soot to the ceiling, the air itself readily escapes through the porous plaster that is simply spread upon the laths, but leaves its dust and soot behind, and thus discolors the plaster; but through the more compact plaster upon the laths, where they are actually nailed to the joists, it cannot pass nor deposit dust, and accordingly such parts remain white or of their original color.

The fact of heated air thus ascending and remaining at the upper part of a room, furnishes a hint as to the most judicious construction of a "fire-place," and it would be a matter of some difficulty to point out any part of our domestic edifices which exhibits such a total absence of rational or scientific principles as an ordinary "fire-place" and its appendages.

Nothing is more common than to see large ill-contrived grates, placed at a considerable height from the hearth-stone, and in many cases actually half way between it and the mantel-piece, beneath a capacious chimney; the absurdity of such an arrangement becomes obvious upon the slightest reflection.

In a grate so situated, the burning fuel radiating heat

ney, or its chimney-pot being less elevated than that of another neighboring chimney, and accordingly a slight wind will blow the smoke from the latter down the former.

A similar result will also take place when the fire is extinguished in the grate to which the shortest chimney belongs, more especially if the apartment be connected with another, by folding doors, as a dining-room with a drawing-room in many modern houses, and a fire kindled in the grate of the latter; for as its smoke ascends, the external air will prefer freely entering the apartments, through the large cold chimney of the dining-room, and introducing at the same time the neighboring smoke, to seeking a limited entrance beneath the doors, from the hall or passage.

Architects, generally speaking, bestow very little attention upon these matters, but sacrifice comfort to the smooth appearance of their favorite plans of construction; and when the dwelling is completed, they appear suddenly to recollect that it requires genial warmth, to render it habitable in winter, and accordingly commence every kind of strange internal alteration, and external disfigurement, for ultimately effecting this most essential purpose.

It is an extremely injudicious plan to "set," as it is technically called, iron grates firmly in brick or stone-work; they may certainly remain steady for a time, but very shortly cracks and fissures appear in the plaster of the "setting," and they become, not only unsteady, but unsightly, and for the following reason:

The first fire that is kindled within the grate, expands its iron-work, exactly as the iron bar was expanded by heat in the experiment at page 291; but not the brick

setting to an equal degree; accordingly, the powerful expansion of the former thrusts the latter away in all directions simultaneously, at the same time cracking the brittle plaster. As the fire decays, the iron-work rapidly contracts to its original dimensions, leaving the setting where it was thrust; a chink, therefore, appears between its edge and that of the iron-work; and this process being continued day after day, the plaster ultimately falls out, and the grate becomes unsteady and unsightly.

An elegant marble mantle-piece is very frequently bulged or distorted from its proper position, and sometimes broken, on account of the expansions and contractions of the bars of iron that are inserted at its back to hold the several parts together; thus the very means adopted with the view of giving permanence or stability, are active agents to the exact contrary.

Many examples might be adduced of injury that is caused by the expansion and contraction of substances when subjected to alternations of heat and cold, but the following may suffice for this inquiry.

Sky-lights, glazed with plate or thick crown-glass when suddenly heated by the sun from without, or by strong gas flames from within, are very liable to fracture on account of unequal expansion and imperfect conduction; and if a shower suddenly covers their surfaces, then the fracture results from unequal contraction and imperfect conduction.

A very large pier-glass was fixed as usual over the drawing-room mantle-piece; the fire-grate was piled with fuel; this was kindled, and the apartment closely shut up for several hours; then, upon opening the door, which was immediately opposite the fire-place, the pier-glass suddenly shattered to fragments, much to the dis-

may of the person who entered; the occurrence was perfectly accidental, but it is thus explained: the pier-glass gradually, and without injury, gained the temperature of the room, but the sudden rush of cold air from the hall, when the door was opened, chilled its surface, and caused contraction, and fracture.

When hot water is suddenly poured upon a thick pane of glass, its upper surface is heated, and greatly expanded before the heat is conducted to its lower surface, which for a time remains as cold as it was originally; an unequal tension is thus established; the upper surface endeavors to bend—in fact, does bend—as a slight arch, but soon causes a total fracture by its want of extreme flexibility.

It would lead into a field of inquiry far too extensive for the present general purpose, to detail the principles upon which ornamental fire-places, and closed stoves, are constructed, as also the contrivances for permitting the escape of foul or vitiated, and the entrance of fresh, or pure air; suffice it to say, that the main fact requiring attention in warming by heated air, is to admit a large volume moderately heated and hydrated, that may slowly and equably diffuse itself throughout an apartment, and not to admit a small volume, intensely heated and anhydrous, by which proceeding, instead of the whole volume of the air in an apartment being of a temperature nearly equable, scorching blasts would occur in one part, and freezing draughts in another.

It must be granted that the practical application of scientific principles to the methods of warming and ventilating domestic edifices, and public buildings, is always very difficult, and frequently utterly abortive; and therefore, after incurring great inconvenience and

enormous expense, in modern hot-air stoves, the "Old English Fire-side" is at length eagerly sought, although the snow-flakes may descend the capacious chimney, whilst the "yule log" blazes upon the hearth.

The extraordinary substance, popularly known as "coal," which is so invaluable in this country as fuel, upon analysis presents the chemist with the same elements as wood, and occasionally a small amount of Nitrogen; and this fact has led many philosophers to imagine that coal consists of the remains of gigantic forests, that were overthrown and buried at the time of "The Deluge."

The extreme importance of coal as fuel consists in the fact of its being extremely hard and compact, and therefore incapable of burning away with great or unprofitable rapidity: a lump of coal placed upon a fire is some time before it kindles perfectly;—whilst a shovelful of fine coal-dust thrown on the fire will instantly kindle as one large and occasionally dangerous flame;—thus affording another illustration of chemical affinity being promoted when attraction of aggregation is overcome.

When a fire of coal is in perfect combustion, a fine yellow flame blazes steadily upon the surface; this is due to the combustion of the Hydrogen and a part of the Carbon; and the latter element being solid, is the cause of the great light of the flame, for that of pure gaseous hydrogen, as we have already discovered, is extremely lambent and pale.

Chiefly from the lumps of coal that are close against the hottest bars of the grate, suddenly issue forth hissing streams of greenish-yellow vapor; and often kindle, as

jets of brilliant yellow flame, or may be kindled by a slip of lighted paper; how are these produced?

The iron bars becoming heated, conduct heat to the interiors of the lumps of coal, and there causes its decomposition into volatile vapor or gas, which cannot burn for want of air, but at length accumulates in sufficient quantity and force to break through the weakest parts of the coals, and issue into the air, and then it either escapes unburnt as greenish-yellow vapor, or kindles at the heat of the surrounding glowing coals, or at that of the lighted paper, and burns as a yellow flame.

Chemically speaking, when coal is heated out of the access of air, it is chiefly resolved into a large volume of gas, called "carburetted hydrogen," though containing more carbon than the gas obtained from the stagnant water of ponds and pools, as described at page 209; and from observance of this apparently trivial fact by the chemist, has originated the gigantic manufacture of "coal gas" for the illumination of our cities, towns, and dwellings.

The discovery of coal-gas was made by a chemist upwards of a century ago, but it was considered as a mere curiosity of the laboratory, and its practical application as an excellent means of artificial illumination, was not entered upon until within the last five-and-thirty years; the merit of this gigantic undertaking is divided amongst a host of the most eminent men, whose names adorn the scientific annals of our country, and who must be considered as the great benefactors of mankind, for the bright illumination of our cities and towns has contributed a most important share towards the prevention of many horrible deeds of darkness.

The merit of first conducting upon a comparatively large scale the examination of the different varieties of coal, the production of gas, its quantity, its purification, its illuminating power, and the construction of the argand-burner for its combustion, is solely due to a philosopher of the present day, who, educated in the same school of Inductive philosophy as his great predecessor, has adorned the science of Chemistry with numerous discoveries and experiments, more particularly in those departments relating to the recondite functions of organized beings, and to the extraordinary nature of organized products; and whose extensive, varied, and sound information concerning the whole science, and clear explicit manner of teaching its facts by lectures, is certainly without parallel; and whose "Manual is the best collection and arrangement of chemical science existing."

The expressions used by a pupil regarding his master in the chemistry of the "olden time," are here copied, with sincerity and gratitude, by a pupil, as applicable to his first instructor in the chemistry of the present day; —"he is a man not of words, but of deeds; a philosopher who eminently seeks to render science popular and intelligible to all capacities."

Returning to the fuel, from whence the vivid jets of gas issued and led to the above passing notice of its discovery and applications, we discover that when the volatile hydrogen and part of the carbon are thus consumed, the yellow flame ceases, and the remaining carbon, containing no volatile matters, but generally contaminated with earthy matters, then enters into combustion, constituting the glowing of the cinders, and producing carbonic acid alone, which being invisible, the fire is said to "burn

clear;" this is more particularly the case during a "frosty night," because the external air being extremely cold, and that of the room extremely warm in comparison, the latter rushes towards the fire, or fans or blows it with greater force in its rapid endeavor to escape through the chimney to the cold air without, than it does when there is not so great a difference between the temperature and the specific gravity of the interior and the exterior atmosphere.

Upon the surface of the red-hot glowing cinders, a beautiful pale blue flame often appears; it results from the carbonic acid that is formed near the lower portions of the fuel in its ascent through the upper, combining with more carbon, and producing an inflammable compound, called "carbonic oxide;" the same flame also appears upon brick and tile kilns, which are heated by coal ashes; and in such situations it has been occasionally mistaken for the "ignis fatuus."

The blue flame is supported by the oxygen of the air combining with the excess of carbon, so that carbonic acid is again produced; and this is the reason that a piece of paper cannot be lighted with readiness on the top of a "cinder-fire," the heat may be sufficient to char the paper, but it cannot inflame, because it is enveloped by the carbonic acid, which is slowly rising; if this be quickly dissipated by the breath, or by suddenly opening the door, the paper thus freed is fanned into flame by the contact of the air.

If the piece of paper be held amidst the glowing cinders near the bottom bars of the grate, where the fresh air first arrives, it will generally kindle immediately, but will not do so if the cinders are only dull red hot,

because such degree of heat, though capable of producing volatile matter from the paper, is incapable of kindling such product; indeed it requires a white heat for its accension; this is obtained either by fanning the fire, or blowing it with the bellows, to excite more rapid chemical affinity between the elements of the fuel and the oxygen of the air.

We frequently hear of thatched buildings, barns, and hay-ricks being accidentally set on fire, from the wadding of a gun incautiously discharged near them, and lodging in the thatch; the wadding may not be hot enough to do this immediately, but by remaining in the thatch or hay for a time, it is fanned by the wind into flame, and then instantly establishes an extensive conflagration.

The bright and dark spots presented in a "clear glowing cinder fire," depend upon the intensity of the combustion of some parts of the fuel being greater than others; and these are liable to great variations, by the draught of air proceeding towards the fire; and whilst watching such variations, the imagination soon becomes active in discovering grotesque resemblances between the forms of the fuel and those of familiar objects.

When the fire that has afforded so much information is "burnt out," the ashes in the grate consist of carbon and a small portion of earthy matters; the carbon is capable of burning in a very strong heat, and the ashes are accordingly collected as fuel for tile and brick kilns.

The utility of coal as a source of artificial heat and light needs no comment; the wisdom and beneficence of The Almighty, displayed in the occurrence of extensive

strata of coal where forest fuel is scarce, calls forth our admiration and gratitude.

In this country, "a land whose stones are iron," these ores could not be obtained without the aid of coal, to produce steam as the motive power of the engine, and draw them forth from the mine; neither could they be reduced to the metallic state, without the agency of coal and limestone. We accordingly find that The Creator has associated the ore of iron or the "iron-stone" with the very agents required for its extraction and reduction.

But the incessant demands that are made upon these subterranean stores of treasure, compel the miner to descend to greater depths, and to encounter greater perils, than were originally needed; and most particularly on account of the air of the mine being rendered inflammable and explosive, by a gaseous exhalation of carbon and hydrogen, similar in composition to the "carburetted hydrogen" or stagnant waters, as mentioned at page 209; this in coal mines is called "The fire-damp," to distinguish it from the natural exhalation of carbonic acid gas, that frequently occurs in limestone and chalk quarries, which is not inflammable, but produces suffocation, and is called "The choak-damp.

"The fire-damp" was long unconquerable, and the most terrific explosions, attended with dreadful loss of human life and destruction of machinery, were of extremely frequent occurrence; but The Almighty, who ordained its presence in the mine, permitted the great philosopher—to whose memory a feeble tribute has been paid during this inquiry—permitted him, to reflect, examine, and experiment upon its habitudes and composi-

tion, and ultimately to succeed in perfectly effecting its subjection.

From the statement at page 126, it will be evident that flame requires a very high temperature for its existence, or else spontaneous combustion would be common during the heat of summer: and from the statement at page 78, it will be learned that metals are the best conductors of heat which are known to man.

These two facts were reasoned upon by the philosopher thus;—as flame requires a high heat for its existence, and as metals are the best conductors of heat they, when applied to flame, should conduct away its heat, and cause extinction.

The experiment was made with success, and its practical application immediately followed, for safely illuminating a mine contaminated with "Fire-damp;" the flame of a candle being surrounded with metallic gauze, through the apertures of which the "Fire-damp" passed, kindled at the flame, burned within the gauze prison, but could not escape from it as flame to explode the surrounding atmosphere, because the good conducting power of the metal deprived it of heat; and thus was a fiery enemy converted into a fettered slave.

The principle of this invaluable invention of the "safety lamp," may be experimentally demonstrated by the following simple arrangement; indeed it is the form in which a flame was first protected from kindling the "fire-damp" of a coal mine.

Provide a cylinder of fine wire gauze, such as is used for sieves and window-blinds; let it be about ten inches long, two inches in diameter, and closed at one end with wire-gauze; take a lump of soft clay, and mould it around

only limited access of air, it becomes "stifled coke;" and this consisting chiefly of solid carbon, is a form of fuel eminently calculated for the reduction of iron, and other metals from their ores; it burns with extreme steadiness, and great intensity of heat, and contains no sulphur, which "gas-coke" invariably does; hence the peculiar odor of burning brimstone emitted from ordinary coke fires, if the draught of the chimney be not powerful and rapid.

The mass of the globe hitherto explored, consists of the oxides of the metals, Aluminum, Silicium, Calcium, and Magnesium, and their combinations with each other, and with various acids, as mentioned at page 30. These are popularly called earths, and they do not admit of reduction to the metallic state by charcoal, coal, or coke. Accordingly, they are invaluable for the artificial construction of furnaces, for the reduction of the ores of ordinary metals, that are found naturally imbedded in them.

Some of the metals either found upon or beneath the surface of the earth, are so nearly pure or elementary, as to admit of immediate application to useful and ornamental purposes;—Platinum, Gold, Silver, and Mercury, for example; whilst others, as Iron, Copper, Tin, and Lead, are found combined with non-metallic elements, and require chemical skill for their reduction before they admit of application to the purposes of life.

The former are called "native metals," the latter "metallic ores;" many of both were known at a very early period, for in the Book of Numbers is a passage remarkable for containing the names of the metals then in common use, viz:—

"Only the Gold and the Silver, the Brass, the Iron, the Tin, and the Lead."

And again, in the Book of Deuteronomy, it is written:—

"A land whose stones are iron, and out of whose hills thou mayest dig Brass."

The opinion of the most learned commentators concerning this passage, is corroborated by science, viz., that the word "Brass" either means "Copper," or the most abundant ore of that metal, called "copper pyrites," or "sulphuret of copper," which is dug out of the earth, and is precisely similar to brass in its color and lustre.

Brass is not a metal, but an alloy, or compound of Copper and Zinc, and it has never been discovered in a native state; it was, and is artificially formed by melting Copper, or its ore, with that of Zinc; although this metal was not formerly known, pure and elementary as it is at present, its lapideous ore was well known, and used in metallurgical operations.

That much was ascertained regarding the art of working metals in the earliest ages, will be evident upon perusing the first Books of Holy Writ; mention is made of "the iron furnace," and of the metal itself, as employed for swords, knives, axes and tools for cutting stones, and the lavish employment of all the metals in the construction of the Tabernacle and the Temple.

Of late years, the nature and properties of the metals have been most attentively studied by the chemist, and he is enabled to obtain them pure, or extract them from their ores with great precision, and in vast abundance; and in consequence of the excellent conducting

power, even of some of the most common metals, they become invaluable for the construction of vessels in which water may be converted into vapor with extreme facility, to constitute the motive power of the steam engine.

Culinary utensils, of metal, enable us to prepare food more economically and perfectly than could be done in vessels of earthenware, or other imperfect conducting materials; and if it were not for the metals, we should be reduced to the condition of those Indian tribes who are yet unacquainted with them, who make rude vessels of the bark of trees, sewn together with thongs, to hold water, in which the food is placed, and then the water is heated to its boiling point by the successive immersion of red-hot stones.

In the earliest ages of the world, it is reasonable to conclude that man sought repose from his labor soon after sunset; but, in the course of his numerous operations upon matter, he would soon discover that the combustion of various organic productions might be employed, not only as sources of artificial heat, but of light.

It is impossible to determine how the wonderful phenomenon of combustion was originally displayed to man; but one thing is certain, that he soon became aware of its power, and that it engaged his attention on account of its beauty and utility.

From this inquiry regarding the Chemistry of the Four Seasons, which is now drawing to its close, it is evident that the chemist is permitted to effect wondrous and strange changes upon the various forms of organic and inorganic substances that are presented in the vast laboratory of Nature; and although he may mix and

unmix, combine and decompose, gather and scatter, be it remembered that he can neither annihilate nor destroy. The power of annihilation and destruction is vested in the Hand of The God who created all things.

The phenomenon of combustion appears to contradict this assertion regarding the non-destruction of matter; for no expression is more common than that of "destruction by fire;" yet, when accurately considered, this destruction is only found to be apparent, and not real.

Fire was anciently regarded as a peculiar, distinct principle or element, having a specific or inherent power of destruction; and in this sense it repeatedly occurs in many of the most sublime and forcible passages of Holy Writ; but science has been permitted to discover that Fire, so far from being an element, is the invariable result of intense chemical attraction between two or more substances.

During ordinary combustion, the elements of the combustible or inflammable substance exert affinity for the oxygen of the air, and produce compounds which, in the generality of cases, are gaseous or vaporous, and therefore elude observation; but they admit of detection by the chemist, and from them he can educe or draw forth elements, the sum total of which exactly equals the original weight of the combustible substance; therefore, when a substance is burned, or apparently destroyed by fire, its physical form alone is changed; but its elements are perfectly unchanged, or, in other words, the elements of the combustible have been induced by elevation of temperature to relinquish their original affinities, and to assume new, but definite arrangements. These, in all ordinary cases, are carbonic acid and watery vapor.

Such compounds are ordained to travel throughout the Creation; and under the recondite powers of vitality, are decomposed, and their elements secreted into the form of woody fibre, and other organic matters, and thus again presented as fuel, which again produces the same compounds, and so on, perpetually traveling, and illustrating, at every change of their affinities, the indestructibility of matter, and the wisdom and power of the Creator.

All substances of organic origin are combustible, but all are not equally fitted for employment as sources of light and heat; the chemist, extending his researches regarding the oils expressed from seeds, or obtained from animals, discovers them to be precisely similar as to the number and nature of their elements, viz., Carbon, Oxygen, and Hydrogen, the latter element being in great excess or abundance, and conferring extreme inflammability upon their vapors; but they do not contain Nitrogen; if this element were present, in vegetable and animal oil or fat, these proximate principles could not be advantageously used as sources of artificial light, because during combustion, in addition to the production of carbonic acid and water, a considerable portion of Ammonia would be produced, and its odor would be as intolerable and fatal as that emitted by burning or putrefying flesh.

The organic matters used for artificial light, be they liquid as oil, or solid as fat, require to be raised into vapor, before they will burn; this is effected by the capillary attraction of the cotton wick of a lamp or candle, which raises the liquid oil, or melted fat, to its upper or red-hot portion, where it vaporizes, and then burns with a brilliant and useful flame.

Wood is invaluable as fuel, because it does not contain nitrogen, and the same remark is applicable to many of the best kinds of coal; some do contain a small portion; but little inconvenience is experienced from the production of Ammonia, in the manner after which such coal is usually burned, it being soon diffused throughout the enormous volume of the atmosphere, and likewise neutralized by acids that are simultaneously formed during the wonderful phenomenon of combustion.

On account of heat being evolved during combustion, a notion is entertained by some physiologists that the heat of the animal body depends upon the burning of the carbon of food, and a statement is made that the "human frame is an apparatus eminently fitted for combustion, or, a species of natural stove."

"God created man in His own image, in the image of God created He him."

The body of man "is fearfully and wonderfully made, in knowledge too excellent for attainment;" and it does not behove philosophy to denote a recondite work that contains a portion of the Divine Essence, by the common name of a laboratory furnace for the combustion of coal.

The very different sensations that we experience upon touching different substances, having similar temperatures, depends upon their relative conducting powers; thus, in a room, a thermometer applied to a silver cup, a glass tumbler, an earthenware basin, and a wooden box indicates that they are all alike in temperature; but upon placing the hand in contact with these different objects in succession, the cup feels cold, the glass comparatively warm, the basin warmer, the box warmest; because the metal draws or conducts from the hand heat

with the greatest swiftness, the glass next, then the earthenware, and lastly the wood; which is so bad in conducting power, that the heat of the hand remains almost at its original point of contact.

If we step out of a warm bed and place our feet upon a carpet they are not chilled; if we do so upon a floor-cloth, they feel icy cold, the one surface being a bad, and the other a good conductor; hence the popular expression of "a warm carpet," and "a cold floor-cloth, although both are of precisely the same temperature; but they differ in texture, and they also differ in conducting power.

The temperature of the Arctic regions is frequently sufficiently low, *i. e.*, 52 degrees below "zero," to freeze mercury upon mere exposure; thus in one of the expeditions to those inhospitable climes of ice, a barometer was accidentally broken, a man held out his hands to catch the valuable mercury; not only did the intense cold freeze the metal immediately, but the frozen mass conducted so much of the natural heat from his hands, that they were frost bitten and soon mortified.

In this country, the cold of Winter is often sufficiently intense to produce dangerous effects upon the living body; it appears to destroy its irritability, and to deprive it of heat; a person feels an irresistible inclination to sleep; he yields, though against his will, and while lost in insensibility his limbs stiffen; if thus asleep he be brought into a warm room, the sudden transition causes his death, but if he be rubbed in the snow he may often recover; the following directions, regarding persons apparently frozen to death or severely frost bitten, are important to be remembered.

Rub the body with snow, ice, or cold water; restore

warmth by extremely slow degrees; it is highly dangerous to apply heat rapidly, because mortification may take place, since the vessels of the body are too much weakened for the immediate resumption of their ordinary functions.

The metal Mercury is always liquid, even during the most intense cold of Winter in this climate, and for its congelation the chemist is compelled to employ a complicated yet powerful means of artificial cold; he then discovers the curious fact that mercury contracts in freezing, so very considerably, that its specific gravity is increased from 13.500 to 15.500.

Accordingly, if one bottle be filled with Mercury and another with Water, and the mouths of each firmly secured, upon placing them simultaneously in a powerful artificial cold, the mercury, when it freezes, will form a lump that can be shaken about in the bottle; whilst the water when it freezes, will burst the bottle in which it was confined.

Water is inadmissible as a thermometric liquid, on account of its anomalous expansion when cooled below 40 degrees; and the two liquids with which thermometers are usually filled, are Mercury and Alcohol; the former requiring a temperature of 640° for its ebullition, is particularly suited for indicating ranges above 212 degrees; but on account of its freezing at 45 degrees below "zero," it cannot be employed for any lower ranges of temperature; whilst Alcohol, which boils at 180 degrees, is unfit for high ranges; but eminently suited for low ranges of temperature, as it has never been frozen by natural or artificial cold.

When a volume of air is perfectly tranquil, at an elevated or a low degree of temperature, its power of com-

municating heat to the body, in the one case, is very feeble; and its power of abstracting it in the other, is extremely small; and this appears to depend upon the non-conducting power of this wondrous medium, to which reference has been so frequently made during our inquiry regarding the chemical phenomena of The Four Seasons.

Thus, the confined air of a room may be heated to 260 degrees, *i. e.*, 48 degrees above the boiling point of water; and a person may walk into and out of this atmosphere with impunity, though any attempt to remain in it generally occasions difficult breathing, and a painful sensation about the eyes, but the skin remains parched and dry.

In some processes, demanding a high temperature, the air of a chamber is often heated to 300 degrees; and the workmen, who are used to it, can enter and remain several minutes without much inconvenience.

The temperature of the atmosphere in the Arctic regions has been observed as low as 55 degrees below "zero," during a calm; and at this extreme degree of cold, Mercury readily froze, yet not the slightest inconvenience was suffered from exposure to the open air by a person well clothed, if he remained still; but if he walked rapidly, and thus put the air in motion, it abstracted heat from the body and produced the most painful sensation of cold.

As confined air is a bad conductor of heat and cold, the terms being merely relative, we immediately discover the use of "double windows" and "double doors," both in Summer and Winter; the stratum of air enclosed between these contrivances, preventing accession of heat in the one instance, and of cold in the

other; this fact has been already illustrated in the case of the plants, at page 104.

The terms "heat and cold" are in popular use, and denote the relative state of the body with regard to the temperature of surrounding objects; thus we may imagine an atmosphere so intensely cold, that a mass of ice would impart a sensation of heat; and on the other hand, an atmosphere so intensely hot, that a flask of boiling water would impart a sensation of cold.

The sensation of heat and cold may be produced, by the same substance, at the same time and at the same temperature; for example, place three basins upon the table, pour into one of these ice-cold water, into another water at 50 degrees; and into the third water at 100 degrees; plunge the left hand into the ice-cold water, and the right hand into that at 100 degrees, let them remain for about a minute, then suddenly plunge both into the water at 50 degrees, the left hand will feel warm, and the right hand feel cold.

The left hand had heat abstracted from it by the ice-cold water, and therefore experienced the sensation of warmth, by the communication of heat, when plunged into water at 50 degrees; whilst the right hand had heat communicated to it by the water at 100 degrees; and therefore experienced the sensation of cold by the abstraction of heat from it when plunged into water at 50 degrees.

If the air be a non-conductor of heat, why should it instantaneously expand by the application of that agent, as in the experiments detailed at pages 65 and 66; or why,—as those who have ascended with balloons tell us,—should the enormous volume of gas, in the silken

globe, instantaneously expand when it emerges from a dark cloud into bright sunshine?

The expansion cannot result from conduction, radiation, or convection, the latter power being placed quite out of the question as regards the balloon, because its upper part is the first that meets the heat; whereas, the reverse condition is necessary for the establishment of convective currents: the following explanation of the phenomenon, both as regards the "air thermometer" and the "gas balloon" is probably correct.

The individual atoms of air in immediate contact with the interior of the glass flask, or the individual atoms of gas in immediate contact with the interior of the silk globe, are suddenly expanded by the mere heat of contact, into many times their original volume; they do not transmit this heat instantly to other atoms, yet they do transmit the pressure, that results from their enlargement of volume in all directions, instantaneously; room must be afforded, the whole is a mobile volume, and the whole thus appears to expand by the accession of heat to the atoms of air or gas, which constitute the film, as it were, in contact with the glass flask or the silk globe.

When a heated solid, such as the "iron-heater of the tea-urn," is suspended in the air, several causes are active in lowering its temperature; one may be an extremely feeble conducting power of the air, which in all practical matters needs not to be regarded; another is extremely powerful radiation from the actual mass of the body; another is the rapid convection that it establishes by mere contact with the air, and these two causes chiefly effect a reduction of temperature or accelerate the cooling of the solid body.

The constant agitation of the air by convective currents, may be proved by admitting a sunbeam through a hole in a window shutter into a perfectly dark apartment, and then all the motes contained in the air, pierced by the light, will be observed in commotion; or the effect may be heightened by throwing a little dust of "lycopodium" in the path of the ray; these small particles of matter indicate the agitation and unsteadiness of the air, by being mechanically carried in its currents the same as feathers thrown in the open air denote the direction of the wind, or straws thrown upon running water betray the course of its stream, though it may appear motionless.

As the air, and all gases, are thus so extremely susceptible of alterations in their volumes, by fluctuations in natural or artificial temperatures, it becomes a matter of great difficulty to ascertain their specific gravities with correctness; and such experiments can only be performed by most experienced chemists, but the following statement may convey a notion regarding the proceeding.

In taking the specific gravities of gases and vapors, the chemist does not generally refer these to the "Water standard," as with liquids and solids, but to an "Aërial standard," namely, the atmosphere itself, and a temperature of 62 degrees, and at the mean barometric pressure of 30 inches. To explain this proceeding in simple terms let us suppose as follows:

A glass globe is selected, exhausted of its air, and its "tare" accurately taken; air is then admitted to fill the globe, and it is found to weigh 1000 parts; the mercury in the barometer standing at 30 inches, and that in the thermometer at 62 degrees; thus indicating that

the air is at its mean pressure, and at its mean temperature.

The volume of air, thus weighing 1000 parts, is then perfectly exhausted from the globe, and its place supplied with an equal volume of Oxygen, under precisely the same conditions of pressure and temperature; but this volume of the elementary gas will weigh 1111 parts; it is therefore heavier than the air, or its specific gravity, as compared with air, is as one and one hundred and eleven thousandths to one thousand, or decimally thus:—S. G. of Air = 1.000, or Unity; S. G. of Oxygen = 1.111.

The chemist removes the Oxygen, and supplies its place with an equal volume of Chlorine; but this will weigh 2470 parts; it is more than twice the specific gravity of the Air, or decimally thus:—S. G. of Chlorine = 2.470.

The place of the Chlorine is then supplied with a volume of Carbonic acid, and it will weigh 1500 parts; it therefore is exactly one and a half times heavier than air, or its S. G. is = 1.500.

Proceeding in this manner with Nitrogen, its volume will not weigh even 1000 parts, but only 972 parts; it is therefore lighter than air, or its S. G. is = 0.972.

Lastly if the globe be filled with Hydrogen, its volume will not weigh even 972 parts, but only 69 parts; it is therefore lighter than either Nitrogen or Air, or its S. G. is = 0.069; and as Platinum is the heaviest, so is Hydrogen the lightest form of ponderable matter.

Observation, experiment, and analogy, tend to excite our wonder, admiration, and gratitude, regarding the

miraculous provision that is made by the Almighty for the protection of His creatures.

How admirably adapted to their purposes are the substances provided for the clothing of animals, and which man strips from them to form garments for his own protection! Animals are preserved from the piercing blasts of winter by clothing which retains nearly the whole of their vital heat; what is its composition?

Almost incredible is the answer of the chemist, namely, that it consists of the ultimate elements of the atmosphere, Nitrogen, Oxygen, Hydrogen, and Carbon—most wonderfully, most mysteriously elaborated under the influence of vitality, protecting and at the same time adorning.

"Clothing, which grows from the bodies of animals, in quantity suiting the climate and the season, is reproducible if partially destroyed by accident; in hot climates, the coat of quadrupeds is short and thin, but it thickens with increasing latitudes, and yields soft and abundant fleeces."

"At the poles it is externally shaggy and coarse, internally shorter and fine, as in the skin of the arctic bear. How defensive is the fur of amphibious animals, the beaver for example;—how abundant and smooth upon birds, as feathers shutting up the heat of their warm blood, and opposing no resistance to the air through which they fly!"

"The birds of very cold regions have plumage almost as bulky as their bodies; and those which live much in the water, have additionally both a defence of oil on the surface of the feathers, and the interstices of the ordinary plumage filled with delicate down, a bad conduc-

tor, which abounds particularly on the breast, as it in swimming first meets and divides the cold wave."

"Then there are animals with warm blood which live in the water; for example, the whale, seal, and walrus: but neither hair nor feathers oiled would have been a fit clothing for them; they accordingly derive protection from the cold water, by the enormous amount of blubber or fat which surrounds their bodies; it is a non-conductor."

The bad conducting power of the earth as regards heat and cold, has been already mentioned; and hence in Winter, springs of water never freeze; they become remarkable features in a snow-clad country, the warm liquid water gushing from the earth, and flowing for a considerable distance before the cold air can chill and bind it in icy fetters.

Throughout the Creation everything is admirable, everything is beneficently fitted for its destined purpose; and the more that we learn, the more do we wish to learn, for we soon become sensible of the extreme insignificance of our knowledge, when we compare it with the contents of the mighty volume that is unfolded for our perusal.

"He sendeth forth His word and melteth the snow."

As we discovered the transition of flowing water into solid ice to be a slow and gradual process, so shall we discover that the conversion of solid ice into flowing water is unattended by sudden and abrupt disturbance of physical state, and thus gain another proof of the wisdom and beneficence of The Creator, and of the miraculous order and harmony of His works.

A few experiments of the chemical laboratory will

serve as introductory to the extraordinary phenomena attendant upon the liquefaction or thawing of ice and snow.

Place a lump of clean dry ice in a basin; carry this into a warm room, at the temperature of 70 degrees for example; the thaw of the ice will commence, and continue;—immerse the bulb of a thermometer into the water resulting from the thawing or liquefaction; it will indicate 32 degrees;—and will again and again do so, whilst a particle of ice remains; when it vanishes, the water will gradually acquire the temperature of the room.

During the progress of thawing, heat must be entering and unbinding the ice; but, strange to say, it does not confer the slightest temperature; it merely causes liquefaction, or, in other words, the sensible heat of the room combines with the ice to produce liquid water, and is then rendered insensible to the thermometer.

By what term does the chemist denote this extraordinary habitude of heat? He denotes it as combined heat, hidden heat, or more commonly Latent heat; and discovers most important results of its agency throughout the realms of Nature and the provinces of Art.

Select two wide-mouthed bottles, of the same size, and resembling each other in all other respects as nearly as possible; put into one bottle a pound of small pieces of ice at 32 degrees, and pour into the other a pound of water at 33 degrees; place a thermometer in each bottle, and carry them both into a room having a temperature of 47 degrees, and set them side by side, as at page 108; they are thus placed under similar circumstances as regards the heat of the room; and they differ only in the physical nature of their contents, the one holding solid, and the other liquid water.

Preserve the air of the room undisturbed by draughts, observe the thermometers occasionally, and note the progress made by the contents of the bottles in heating; if the liquid water arrive at 40 degrees in the course of an hour, the ice will not melt into water, and attain the same temperature, until twenty-one hours later.

The heat of the room is uniform all this time, but twenty-one times more of it is required in the one case than in the other to produce the thermometric temperature of 40 degrees; or, to place this easily-ascertained, yet extraordinary fact, in another point of view, suppose that, during the twenty-one hours the water received heat, as regularly as during the first hour, namely, 7 degrees, or from 33 to 40 degrees, the whole heat would be expressed by twenty-one times seven, or 147 degrees; the difference between the gain of temperature by the ice and by the water, with equal accessions of heat, is, therefore, 140 degrees; hence 140 degrees become the expression for the amount of thermometric temperature which disappears, which is hidden, or rendered latent during the liquefaction of ice: heat enters the ice, rendering it liquid, but does not produce the slightest rise of temperature.

Let us proceed further with the investigation of Latent Heat. Mix one pound of snow at 32 degrees, with one pound of water at 172 degrees; the snow will immediately melt, and two pounds of water will of course result, but of what temperature? One hundred and two degrees, or half way between the two original extremes, we might reasonably answer; but the introduction of the bulb of a thermometer will indicate the temperature to be only thirty-two degrees, or, in other words, the water is ice-cold.

Thus the warm water, in cooling from 172 degrees to 32 degrees, loses 140 degrees of heat, which heat converts the snow into liquid water most assuredly, but produces no elevation of temperature. Such is the remarkable fact thus elicited by actual experiment, and, therefore, the Chemist is in the habit of stating liquid water to be a compound of ice, and 140 degrees of heat.

The effect of heat upon any form of solid water, ice, snow, hail, frost, is not to raise thermometric temperature during thawing, but merely to produce flowing water; then, this being wholly effected, rise of thermometric temperature immediately ensues, and proceeds until it acquires that of the source of heat. The most acute, the most profound reasoning, could not enable us to predict such an extraordinary result; but it is only one of the many wonders brought to light by chemical experiment, and from it the Chemist discovers the following general law:—

"That in all cases of liquefaction, a quantity of heat, not indicated by, or sensible to, the thermometer, is absorbed or disappears; and that such heat is withdrawn from surrounding bodies, leaving them comparatively cold."

This may be strikingly illustrated in melting a solid substance by the intervention of some chemical affinity, without the direct application of heat.

Thus for example, for the solution of salts, such as nitre and common-salt, to ensue in water, they must be melted, and they actually melt in the latent heat that the water contains, and therefore the act of solution is attended by cold.

If an ounce of finely-powdered nitre be placed in an ale-glass filled with water, and then solution rapidly pro-

moted by stirring, the introduction of the bulb of a thermometer will denote depression of temperature, and so will the exterior of the glass, for it summons the watery vapor present in the atmosphere to condense upon its surface as dew; a "dew-point" is thus obtained by the solution of the salt, as by the evaporation of the ether in the experiment with the "hygrometer," at page 178.

The chemical constitution of water is not altered by its transition into ice, neither is its affinity for various substances suspended by such change; and although it may feel cold to the touch, it contains latent heat; indeed two lumps of ice have been fairly melted by rubbing them against each other.

When finely-powdered ice or snow is mechanically mingled with finely-powdered common salt, the two substances instantly exert chemical attraction for each other; they melt, heat is absorbed during such liquefaction, and the resulting solution or brine has a temperature thirty-two degrees below the original temperature of the ice, or in other words, the mercury of the thermometer falls to the "zero" of its scale, when its bulb is plunged into this "freezing mixture," that has been so frequently employed as a convenient source of artificial cold, throughout the present inquiry.

Advantage is frequently taken of this strong chemical attraction between salt and frozen water, for removing hard-trodden snow from foot pavements; the salt is merely sifted or sprinkled on its surface, and in the course of a few minutes liquefaction ensues; the brine is then swept away, and the pavement effectually cleansed, it is true, but likewise cooled down to zero, and therefore chills the air much below its ordinary winter temperature.

If we have been walking along the streets for some

distance upon snow, the feet become gradually inured to its temperature; but coming suddenly upon pavement recently cleansed by salt, its intensity of cold in comparison with that we have quitted, becomes painfully sensible to the feet, especially if clad in thin-soled shoes.

Confectioners, by employing a mixture of ice and salt, are enabled to obtain a low temperature even in the very height of summer, for the production of ices for the table; and the salt may be recovered from the brine by evaporation, as at page 58, and employed over and over again for the same purpose, because it sustains no change in its chemical constitution.

A very simple yet extremely instructive experiment, regarding the intense cold of this "freezing mixture," may be performed at any season of the year as follows: pour a large spoonful of water upon the middle of a wooden trencher; place the polished tin canister, that was employed in the experiment at page 151, to stand in this little pool; then fill the canister with the "freezing mixture," adjust its cover, and insert the thermometer through its aperture.

In the course of a very few seconds, the bright polish of the canister will become dim with moisture, because the warm air around wafting against its cold surface is reduced to the "dew-point," and compelled to deposit dew; but the cold is more than sufficient to effect this; the thermometer indicates "zero," and accordingly, in the lapse of a few more seconds, a kind of white smoke will surround the canister; it consists of myriads of crystals of hoar-frost, into which the dew is compelled to change; it is exactly analogous to the "frost-smoke" mentioned at page 336, and in the course of some minutes will thickly encrust the outside of the canister, which

simultaneously acts as the means of their formation and the nucleus for their support, and likewise for reducing the temperature of the water upon which it was originally placed, to the "freezing point;" so that now, taking hold of the knob of the cover, and lifting it, the canister will be found frozen to the trencher.

"That the heat which becomes insensible or latent during the liquefaction of ice and other solids, remains in the liquid and is not lost, is shown by the circumstance of its being again emitted, or given out, during their congelation.

"If a vessel of warm water be exposed in a very cold atmosphere, the temperature rapidly sinks to the freezing-point, and then it begins slowly to congeal; if kept in the same situation, heat is of course abstracted as before; but the thermometric heat remains stationary at about thirty-two degrees, till the whole is frozen; after which the temperature of the ice begins to sink."

Perhaps the result of this experiment is more explicitly stated as follows:—If, when the thermometer is at twenty-two degrees, we expose a vessel full of Water at fifty-two degrees to the open air, and beside it another vessel full of Brine, at the same temperature, with thermometers in each, we shall find that both of them gradually lose heat, and are cooled down to 32 degrees.

After this the Brine—which does not freeze till cooled down to four degrees—continues to cool without interruption, and gradually reaches twenty-two degrees, the temperature of the air; but the pure water remains stationary at thirty-two degrees; it freezes indeed, but very slowly, and during the whole process its temperature is thirty-two degrees;—now why should one liquid refuse to give out heat and not the other?

Is it not much more probable that the water, as it freezes, gradually gives out the heat which it had absorbed during its liquefaction; and that this evolution maintains the temperature of the water at thirty-two degrees, notwithstanding what it parts with to the air during the whole process?

It is easily shown that water, while congealing, is constantly imparting heat to the surrounding air; for a delicate thermometer suspended above it is constantly affected by an ascending stream of air less cold than the air around.

The chemist adduces this fact as another example of a miraculous provision that is beneficially made by the Creator, to mitigate the rigor of Winter, by ordaining that water during its congelation should yield up its stores of latent heat to the ambient air, and thus gradually reconcile animated beings to this wondrous and important physical change. The latent heat would be useless if it remained in the solid water, and is therefore ordained to escape where its presence is needed.

That latent heat present in a liquid, and insensible to the thermometer, becomes sensible if the liquid assume the solid state, may be shown by the following experiment during any season:—Add crystals of sulphate of soda to a pint of boiling water, until a considerable portion of the salt remains undissolved; then filter this hot saturated solution through a piece of fine muslin, into a perfectly clean finger-glass, until it be nearly filled.

Place the glass upon the mantel-shelf, that it may not be shaken,—as it would be if left on the table by the vibration of the floor—close the door and windows of the apartment, that the surface of the solution may not be ruffled, nor become dusty; in fact, take all necessary

precautions to keep the glass steady, and the solution clean.

In the course of a few hours, the solution will have cooled to the temperature of the apartment, and, generally speaking, without depositing crystals; or, in other words, the crystalization of the sulphate of soda is in this case suspended, as that of water may sometimes be when kept unruffled and reduced to a low temperature.

Note the temperature of the air, then gently plunge the bulb of the thermometer into the solution, and very probably crystals will instantaneously form around it as a nucleus, and gradually extend until the whole contents of the finger-glass assume the form of one solid crystaline mass; if this happen, the thermometer will indicate a very considerable increase of temperature; and indeed this will be immediately detected by the hand, upon grasping the outside of the finger-glass.

Why does the heat become sensible? Because the sulphate of soda cannot assume the crystaline form unless it combine with fifty per cent. of water; and during this sudden transition from one state to another, the latent heat that existed to maintain the liquid, is now expelled, or rendered sensible, as not needed to maintain the solid form.

The crystals of sulphate of soda that were originally dissolved to form the solution, contained nearly the same amount of water as those now deposited, although they might have felt perfectly dry to the touch; but if exposed to the air for a few hours, their surfaces, instead of remaining transparent and glassy, will become opaque and pulverulent; and so will the newly-formed crystals, if they be set to drain in a sieve.

The chemist calls the water thus solidified or combined

with crystals, "water of crystalization;" and in the case that we are considering, it is not combined with a very high degree of attraction; so that upon exposure of the crystals to the air, a portion dries out from them, and they become pulverulent, or are technically said to "effloresce."

They may be preserved by placing them in air saturated with aqueous vapor, as in the arrangement at page 61; and thus the chemist manages to keep specimens of most "efflorescent salts;" such as attract water from the atmosphere, or are "deliquescent," he keeps in accurately-stopped bottles; others, again, that undergo no change by ordinary exposure to the air, he keeps in papers or boxes, and calls them "permanent salts."

The suspended crystalization of sulphate of soda is rather uncertain; sometimes crystals will form as the solution cools; at others upon touching it with the thermometer; at others again it will not do so unless briskly stirred with the bulb; very often the merest agitation of the air will determine the formation of crystals, and as often it will fail in so doing; but the phenomenon, if it does not occur by any of the above means, will immediately and invariably happen when a minute crystal of sulphate of soda is dropped into the solution.

No satisfactory explanation has been offered regarding the suspended crystalization of this solution; it is not a solitary instance, for six or seven other salts are known to present the same phenomenon; the sulphate of soda has been chosen on account of its cheapness and abundance; the crystals may be dissolved and employed over and over again.

If a pound of carbonate of soda, and a pound of sulphate of soda, both in crystals, (popularly known as

precautions to keep the glass s... clean.

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o become liquid water, renders latent 140 degrees
but this water, to become steam at 212 degrees,
s latent no less than 960, nay, some experimenters
960 degrees of heat; it matters not how fierce may
the fire, or how vehement the ebullition of the water
ven vessel, its temperature, and that of the steam
ver exceed 212 degrees,—so long as the baro-
ndicates 30 inches as the atmospheric pressure,—
ess of heat from the fire is rendered latent in the
and insensible to the thermometer.

When steam, having a thermometric temperature of
degrees, impinges upon a cold surface, and con-
s into the state of liquid water, it relinquishes its
nt heat, which then becomes sensible to the thermo-
ter.

Hence, in the process of distillation, the steam coming
o contact with the upper part of the cold "worm-pipe,"
condensed, and its latent heat being received by the
rounding cold water, elevates its temperature; and it
also be observed, that such heated water will float

...on the vet colder portion below for a considerable time; ...owever, the distillation be continued, the whole of ...e water in the "worm-tub" will acquire the tempera...re of the steam, and will be unable to condense it any ...nger, so that steam will freely issue from the lower end ...f the worm-pipe, instead of the liquid drops, as at the ...utset of the process.

It is on account of steam thus containing such an enormous store of latent heat, that its power of scalding the body is so great; for whenever steam comes into contact with a surface colder than itself, it condenses, and its latent heat becomes sensible.

If we conjoin this fact with that already stated regarding the cold produced during evaporation, we shall be enabled to explain why it is possible to "blow hot and cold with the same breath."

By gently blowing, or rather breathing upon our cold hands, they instantly condense the watery-vapor of the breath, and its latent heat becomes sensible: the hands are warmed; by forcibly blowing upon our hands, the watery vapor has no time to condense; but the blast incites evaporation from the skin, or abstracts heat from it, so that the hands are cooled.

When a fog occurs during Autumn or Winter, the well-known increase in the temperature of the atmosphere is referable to the latent heat that existed in the watery vapor becoming sensible during its condensation or change to the liquid state; and if wind subsequently occurs, it is accompanied by decrease of temperature, because heat is absorbed or rendered latent by the water, or its evaporation or change into the state of vapor.

Thick and substantial walls in the interior of houses, become damp, and often very wet, in certain states and

changes of weather; they are so massive as to retain an acquired temperature for a long time, and during a winter's frost become cooled throughout; upon a sudden thaw attended by a very humid state of atmosphere, the vapor or moisture of the air is condensed in the liquid state upon these cold surfaces, because they abstract its heat and consequently cause it to run down in the form of water.

A most extraordinary fact is discovered by the chemist during his researches concerning the conversion of water into vapor; namely, that whatever may be the temperature of such vapor, it invariably contains the same quantity of heat.

The details of this discovery cannot be touched upon in this general inquiry; but a few examples of the fact may be presented, and when accurately and minutely considered, they display much to excite our wonder and astonishment regarding the habitudes of water with heat, and the important part enacted by this extraordinary compound, in all its physical states throughout The Four Seasons.

A certain weight of steam having a thermometric temperature of 212 degrees, if condensed at 32 degrees, gives out 180 degrees of its original sensible heat, and 950 degrees of latent heat; so that the whole amount of heat contained in the steam is equal to 1130 degrees.

The same weight of steam of 250 degrees of thermometric temperature, similarly condensed at 32 degrees, gives out 218 degrees of sensible heat, and 912 degrees of latent heat, so that the whole amount of heat contained in the steam, is again equal to 1130 degrees.

Lastly, the same weight of steam at 100 degrees of thermometric temperature, similarly condensed at 32 de-

grees, gives out 68 of sensible heat, and 1062 degrees of latent heat; so that the whole amount of heat contained in the steam, as in the two former instances, is equal to the constant number of 1130 degrees.

Upon these incontrovertible facts, a law is established to the effect,—that in proportion as the sensible or thermometric heat of steam is increased, so its insensible or latent heat is decreased; and in proportion as its sensible heat is decreased, so its latent heat is increased.

Carrying forth the results of these experiments into the vast laboratory of Nature, the chemist is led to the conclusion, that similar weights of the vapor of water, produced by the different temperatures of Spring, Summer, Autumn, and Winter, contain a similar and a constant amount of heat; and without this agent, so miraculously treasured by the Almighty, in the vapors and floods, the air and the earth, as already shown, the animated creation could not exist.

Let us now remark and appreciate the beneficial results which ensue throughout Nature by the operation of the unerring laws that we have been considering and endeavoring to illustrate by experiment.

The ice and snow of Winter do not suddenly change into floods, upon the first accession of heat from the sun of Spring; did they so change, the earth and its productions would be immediately inundated by the emancipated waters; on the contrary, The Hand of Infinite wisdom ordains, that each mass of ice, each flake of snow, each pearl of frost, shall slowly absorb and render latent a certain amount of heat, and thus gradually become liquid water instead of suddenly changing into a destructive torrent.

And when the long imprisoned waters are freely un-

bound by the genial warmth of Spring, and are exposed to the heat of Summer and the glow of Autumn, they display the same Beneficence of The Creator in the adjustment of their temperature to animated beings, as they manifested during the cold of Winter.

Warm winds now glide over the liquid surface of the lake chosen as our example at page 300; the surface water gains heat by contact, but loses specific gravity, or in other words, floats upon the colder water beneath; the temperature of the surface may be 62 degrees, whilst that of the depth remains at 40 degrees; no sudden elevation of temperature can ensue from conducting power; the fishes become slowly inured to the change that at length is established, by the mechanical agitation of winds and breezes.

In concluding this rapid inquiry regarding the principal phenomena of The Four Seasons which admit of elucidation through the medium of the Science of Chemistry, it becomes necessary to imprint upon the mind of the young student of Nature, the magnitude of the Earth, as compared with the size of man; and then instead of his feeling surprise that so many of its vast phenomena yet remain uninterpreted, he will rather wonder that the Creator has permitted so many to be discovered.

The Earth is 8000 miles in diameter; the atmosphere is calculated to be 50 miles in altitude; the loftiest mountain peak is calculated to be five miles above the level of the sea, for this height has never been visited by man; the deepest mine that he has formed is 550 yards; and his own stature does not average six feet.

Therefore, if it were possible for him to construct a globe 800 feet—or twice the height of St. Paul's cathe-

dral—in diameter, and to place upon any one point of its surface an atom of $\frac{1}{1000}$th of an inch in diameter, and $\frac{1}{100}$th part of an inch in height, it would correctly denote the proportion that he bears to the earth upon which he stands.

If he would condescend to bear in mind the fact of his own insignificance in comparison with the magnitude of his dwelling-place; that he is but a mere atom in the stupendous scale of Creation, it would act as a salutary check to the dogmas that he so frequently pronounces, regarding the causes that MUST be operating above and below the huge surface of the earth, because he finds such and such phenomena, after climbing upon a natural hillock, or creeping within an artificial burrow.

How magnificent is the language of Scripture when extolling the Omnipotence of God and the grandeur of His works!

"It is He that sitteth upon the circle of the earth, and the inhabitants thereof are as grasshoppers; that stretcheth out the heavens as a curtain, and spreadeth them out as a tent to dwell in.

"Behold the nations are as a drop of a bucket, and counted as the small dust of the balance; behold he taketh up the isles as a very little thing."

Upon due reflection concerning these important and astounding matters, we are immediately led to exclaim with the Psalmist, "Lord, what is man that Thou art mindful of him, or the son of man that Thou regardest him!"

Yet has The Almighty, "The Father of Lights, in whom is no variableness, neither shadow of turning," in His abundant goodness, vouchsafed to man, "certain

knowledge of the things that are, namely, to know how the world was made, and the operation of the elements." "The beginning, ending, and midst of the times: the alterations of the turning of the sun and the change of seasons."

We have thus endeavored to trace a few of the wonderful phenomena of The Four Seasons, which admit of interpretation through the medium of the science of Chemistry, from the Spring, when all Nature is bursting into life, to the Summer, when glowing with beauty and sweetness; then to the Autumn, teeming with all the purposes for which this vitality and perfection were called into being, and finally to the Winter, when it is shrouded in sleep and repose.

We have seen that "everything is beautiful in his season," that everything displays the power and goodness of God.

"All the works of the Lord are good; and He will give every needful thing in due season."

"So that a man cannot say, this is worse than that, for in time they shall all be well approved."

The study of Chemistry and of all the high sciences is well suited to keep down a spirit of arrogance and intellectual pride, "for, in disentangling the phenomena of the material world, we encounter things which hourly tell us of the feebleness of our powers, and material combinations so infinitely beyond the reach of any intellectual analysis as to convince us at once of the narrow limitation of our faculties.

"In the power of grasping abstract truth, and in the power of linking together remote truths by chains of abstract reasoning, we may be distinguished from the lower order of the beings placed around us; but in the exer-

cise of these powers, we bear perhaps no resemblance whatsoever to the Supreme Intellect.

"Applied to an Almighty Being with the attribute of ubiquity, in whose mind all things past and to come coexist in eternal presence, time and space have no meaning, at least in that sense in which they are conditions of our own thoughts and actions.

"To Him all truth is as by intuition; by us, truth is only apprehended through the slow and toilsome process of comparison; so that the powers and capacities, forming the very implements of our strength are also indications of our weakness; in some of our capacities, we may, perhaps, exhibit a faint shadow of a portion of our Maker's image; but in the reasoning power, of which we sometimes vainly boast, we bear to him no resemblance whatsoever.

"Simplicityof character, humility, and love of truth, ought therefore to be—and generally have been—among the attributes of minds well trained in philosophy."

"After all that has been done since the thoughts of man were first turned to the phenomena of the material world —after all the boasted discoveries of science, from the first records of civilization, down to our own days—those glorious passages of the Old Testament, (Job xxxviii.,) contrasting the power and wisdom of God in the wonders of His creation, with man's impotence and ignorance, have still, and ever will continue to have, not merely a figurative or poetical, but a literal application."

When "God answered out of the whirlwind" concerning the mighty works of His Omniscience and Omnipotence, He deigned to hold direct converse with man, to convince him of human ignorance and imbecility.

The wonderful and beneficial phenomena of the Creation which are acknowledged and appreciated even by the most unenlightened and obdurate minds, in this unapproachable language are displayed and set forth in a series of the most sublime and powerful metaphors, that are instantly apprehended, and carry conviction to the soul of man that "He that built all things is God."

"Before such an Interrogator we can only bow in humble adoration."

"The study of the laws of Nature may strengthen and exalt the intellectual powers; but strange must be our condition of self-government and tortuous our habits of thought if such studies be allowed to co-exist with self-love and arrogance and intellectual pride."

"There are yet hid greater things than these; for we have seen but a few of His works."

Although the amount of scientific knowledge at the present day may be justly called great, yet it is as nothing in comparison with the magnitude of the objects of the Creation, and while it shall please God to continue us in this world where so much is to be done, and so little to be known, we must employ the talents entrusted to our care with unremitting zeal and humble confidence, and wait with patient expectation for the time in which the soul returning to the bosom of its God, "shall be satisfied with Knowledge."

APPENDIX,

CONTAINING

The Names of the Discoverers, Historians, and Narrators of the principal Facts which are embodied in this Work.

Agricola first described Bismuth.

Alison records the hurricane produced during the conflagration of Moscow.

Allen and Pepys ascertained the quantity of carbonic acid that is exhaled by a healthy adult in twenty-four hours; they also made important experiments regarding Priestley's discovery of the renovation of vitiated air by growing plants.

Applegath and Cowper applied the steam-engine to the printing-machine.

Archimedes is supposed to have discovered what is now termed the "specific gravity of gold."

Bacon, Lord, must be considered as the founder of "Inductive Philosophy," real knowledge being in his view "not a couch whereupon to rest a searching and restless spirit; or a terrace for a wandering and variable mind to walk up and down with a fair prospect; or a tower of state for a proud mind to raise itself upon; or a fort, or commanding ground for strife and contention; or a shop for profit and sale, but a rich store-house for the glory of the Creator and the relief of man's estate."

Balard discovered Bromine.

BALDWIN made several experiments upon phosphorescent substances.

BANKS, Sir J., remarked the fact of the sun-burn on the back of a silver-fish, when exposed to sunshine after the felling of the trees around the pond.

BASIL VALENTINE discovered the metal Antimony.

BERARD accurately examined the changes sustained by the atmosphere during the ripening and decay of fruits.

BERGMAN introduced methods of analyzing Waters.

BERTHOLLET proposed chlorine as a bleaching agent.

BERZELIUS discovered Selenium. First obtained pure Silicium. Discovered Thorium. Discovered Zirconium.

BERZELIUS and HISINGER discovered the metal Cerium.

BLACK, DR., discovered the composition of Chalk. First proved that the thermometer affords no correct insight into the absolute quantity of heat necessary to produce a given temperature; or, in other words, that bodies have different capacities for heat. Discovered the amount of heat that becomes latent during the thawing of ice and the liquefaction of other substances. Discovered the latent heat of steam.

BOYLE, Hon. ROBERT, corroborated Van Helmont's original experiment with the willow tree. Improved the air-pump, and rendered it an available apparatus for philosophical research. Made the first accurate researches concerning the exhaustion and condensation of air. Records the fact of aroma being retained by the air with persistent force, and traveling with it many miles out to sea. Introduced the form of the air thermometer, as shown at page 294. "Turned his mind with much earnestness to the construction of a scale for thermometers, and seems to have had it in contemplation to set out with the temperature at which water begins to freeze;" but he did not prosecute this inquiry, fearing that many objections would be raised against its practice.

BRADLEY and ROEMER discovered the motion of light to

be progressive, and that it is about eight minutes and thirteen seconds in passing from the sun to the earth.

Brande made numerous and highly important experiments regarding the chemistry of organic bodies. Discovered the presence of Nitrogen in the Alkaloids or active principles of Barks, Opium, &c. Made the first accurate experiments upon a large scale, regarding the destructive distillation of coal, its produce, the purification of the gas, and its illuminating power.

Brandt discovered Cobalt. Discovered Phosphorus. First pointed out the characters of Arsenicum.

Braun discovered that mercury might be frozen by artificial cold.

Callimachus first observed the beauty of the acanthus diverted from its original position of growth; and invented the Corinthian capital.

Canton made many experiments upon phosphorescent light.

Cavendish, Hon. H., demonstrated the composition of nitric acid; and its formation by the passage of electricity through confined air. Discovered the composition of saltpetre or nitrate of potash. First examined the nature of Hydrogen. Discovered the composition of Water.

Celsius introduced 0 and 100 degrees to denote the freezing and boiling point of water; this is the most philosophical scale, and commonly employed on the continent.

Chaptal probably originally proposed the employment of chlorine as a bleaching agent in the arts.

Christison investigated the action of poisons upon plants.

Clayton discovered that inflammable gas might be obtained by the distillation of coals.

Courtois discovered Iodine.

Crawford made numerous experiments upon the capacity of bodies for heat.

Cronstedt discovered Nickel.

Cardan was probably the first to discover that Water expanded when cooled to a certain degree: but the Florentine academicians accurately examined the phenomenon.

Cullen discovered that cold was produced by the evaporation of ether and alcohol at common temperatures.

Dalton investigated many of the phenomena concerning the evaporation of water.

Daniell ascertained the rate of the evaporation of water, during different states of the atmosphere. Invented the only accurate hygrometer for ascertaining the actual amount of watery vapor present in the atmosphere. Brought the barometer to its present state of perfection and excellence.

Darcet discovered that diamonds might be burned; Lavoisier corroborated the experiment, and ascertained that carbonic acid was produced, as from the combustion of charcoal.

Davy, Sir H., discovered Barium, Boron, Calcium, Lithium, Magnesium, Potassium, Sodium, Strontium. The composition of Common-salt, and that Lime, Sand, Clay, Magnesia, Potash, Soda, were oxides of metals. Suggested the existence of Fluorine. Demonstrated the nature of Chlorine. First devised methods of analyzing soils. Discovered that some soils heat and cool more readily than others. Pointed out the doctrine of the proper application of manures. Ascertained the composition of the gas emitted from the mud of stagnant waters. Discovered silica as the coating or clothing of grasses, and melted a wheat-straw into a globule of glass, by intense heat. Explained the philosophy of the old proverb regarding the morning and evening rainbow. Discovered the existence of water in crystals and pebbles of silica. Investigated the nature of flame, the combustion of "fire-damp," and crowned his masterly researches by the discovery of the Miners' Safety Lamp.

Delhuyart discovered Tungstenum.

Descotils and Tennant simultaneously discovered Iridium.

DREBBEL and SANTORIO divide between them the honor of the discovery of the thermometer.

FAHRENHEIT discovered that upon mixing ice and salt, an intense degree of cold is produced. Introduced 32 and 212 degrees to denote the freezing and boiling point of water; and this scale is universally adopted in England.

FARADAY corroborated the fact discovered by Cavendish, of the formation of nitric acid by the action of electricity upon air. Has made the greatest number of discoveries in Electricity of any philosopher. Discovered that Chlorine, Hydrochloric acid, Nitrous oxide, Carbonic acid, and Ammonia, that were formerly thought to be permanent gases, as Oxygen, Hydrogen, and Nitrogen, rather merit the title of vapors, as all of them may be condensed into liquids by pressure and cold, and some even to the solid state, by the greatest artificial reduction of temperature that can be obtained.

FLORENTINE ACADEMICIANS (the) constructed the first instrument to which the term "thermometer" can properly be applied; and it closely resembled the arrangement represented at page 292.

FONTANA constructed an instrument called the "eudiometer," for examining the goodness or fitness of air for the support of life.

FORBES ascertained the probable physical cause of the red color of the morning and evening sky.

FOURDRINIER and DONKIN applied the steam-engine to the manufacture of paper.

FRANKLIN drew lightning from the heavens, and proved its identity with electricity artificially excited; he also proposed the attachment of conductors to buildings. Probably first made the experiment with the nine pieces of cloth, placed upon snow exposed to sunshine.

GAHN discovered Manganesium.

GAHN and SCHEELE decomposed Bone-earth.

Galileo first suspected that the air was a ponderous body. Probably invented the condensing syringe.

Galvani and Volta engaged in a controversy regarding muscular motion; and one of the consequences of their difference of opinion was the discovery of the intimate relation between chemistry and electricity.

Gay Lussac discovered Hyponitrous acid. Proposed the form of the lightning conductor, or "paratonnere," that is represented in this work.

Geber, in the seventh century, first made the substance called "red-precipitate," (oxide of mercury,) from which Oxygen gas was obtained by Priestley in 1774.

Geoffroy constructed the first tabular forms for expressing the force of chemical affinity.

Glauber discovered that vinegar might be obtained by distilling wood, at a red heat; he also gives the first directions for obtaining spirit of salt, *i. e.*, hydrochloric acid; and likewise sulphate of soda; hence the latter is known as "Glauber's salt;" "he was a most industrious man, cast in the true mould of an experimental chemist."

Graham accurately determined the expansibility of liquids by heat.

Gregor discovered Titanium.

Grey and Wall probably made the first remarkable experiments concerning electrical attractions and repulsions.

Hales experimented upon the motion of sap in plants, and their powers of transpiring watery vapor. Invented the revolving ventilators that are commonly used for allowing heated and vitiated air to escape from rooms.

Halley is regarded by several writers as entitled to the merit of fixing upon the boiling point of water as a standard of graduation for the mercurial thermometer.

Hanckwitz first obtained phosphorus upon a large scale, and sold it as a chemical curiosity, at the rate of one hundred shillings an ounce.

HARRIS perfected the lightning conductors for ships.

HARVEY discovered the circulation of the blood.

HATCHETT discovered Columbium. Made the first accurate experiments concerning the hardening principle of shell and bone.

HIELM discovered Molybdenum.

HIGGINS originally laid the foundation of the theory of definite proportions, for the essential facts which have been subsequently followed up and worked out by later chemists, are to be found in his works, dated 1789.

HISINGER and BERZELIUS discovered Cerium.

HOME, Sir E., made the experiments regarding the absorption of heat by the skin of the Ethiopian.

HOOKE discovered the two fixed points for the graduation of the thermometer. Suspected that nitre contained a principle analogous to that in the atmosphere which supports combustion.

HULLS, BELL, and FULTON, divide the honor and merit of applying the steam-engine to navigation.

HYPATIA, a female celebrated for her acquirements in literature and science, towards the end of the fourth century, is said to have invented the "hydrometer" for ascertaining the purity of Water.

INGENHOUZ ascertained the relative conducting powers of the metals regarding heat. Devised experiments in illustration of conductors and non-conductors of heat.

IRVINE made several important experiments regarding the capacity of bodies for heat.

KING furnished the accurate account of the manner in which the Esquimaux built their snow-houses—he was one of the party who went out in the Arctic Land Expedition in search of Ross.

KLAPROTH discovered Uranium. Accurately examined Titanium. Accurately examined Tellurium.

KUNKEL made several experiments upon phosphorescent substances.

LABARRAQUE proved the great power of chlorinated lime and chlorinated soda as preventives of putrefaction and as disinfectants.

LAPLACE made a series of important experiments upon the capacity of bodies for heat.

LAVOISIER discovered the composition of gypsum. Demonstrated the atmosphere to be chiefly a mixture of nitrogen and oxygen.

LESLIE discovered that water might be frozen by the cold produced during its evaporation. Made the first accurate researches upon radiant heat, as regards the manner in which its reception and retention may be affected by surfaces.

LOWITZ made many important experiments concerning the effects of artificial cold upon substances.

LYELL gives the account of the preservation of snow from thawing by the non-conducting power of volcanic dust.

MACBRIDE suspected the presence of carbonic acid in the atmosphere. Discovered that vegetable and animal substances yield carbonic acid gas, by putrefaction and fermentation.

MARCET accurately examined sea-water from various parts of the world.

MAYOW found that bodies during combustion increased in weight, and referred the phenomenon to their "fixation" (combination) of "nitro-aërial particles" (oxygen) from the atmosphere.

MORVEAU originally proved that hydrochloric acid gas and chlorine might be used as disinfectants.

MOSANDER discovered Lantanum.

MULLER discovered Tellurium.

NEWTON, Sir I., by his sagacious views regarding mechanical and chemical attractions, destroyed the ancient notions that the particles of bodies were held together by hooks, rings, points, and wedges. He says, "I use the word attraction

to signify any force by which bodies tend towards one another, whatever may be the cause."—Optics, book iii., query 31. Explained the probable physical cause of the rainbow and analyzed light by a prism of glass. Hinted that the diamond and water both contained inflammable matter. Suggested that the melting point of ice should be taken as the commencement of the thermometric scale, but HOOKE made the discovery that in melting ice, and boiling water, the mercury of a thermometer always contracted and expanded to certain marks.

NICHOLSON and CARLISLE first decomposed water by electricity, and obtained both its elements.

OTTO GUERICKE first publicly demonstrated the enormous pressure of the atmosphere upon an exhausted vessel. Invented the air-pump. Invented the meteorological toy now familiarly known as the "weather-house."

PARACELSUS first mentioned Zinc.

PASCAL proved that the atmosphere decreases in its density in proportion to its altitude. Proposed the employment of the barometer as a "weather-glass."

PEPYS ascertained the important fact, that the leaves of plants are ever active in decomposing the carbonic acid of the atmosphere.

PRIESTLEY discovered Nitrous and Nitric oxide. Discovered Oxygen, by heating a compound formerly called "red-precipitate," in the focus of a burning lens; this compound is now known to consist of oxygen and mercury; these were repelled or unbound by the heat, and the gaseous oxygen obtained free, whilst the mercury mingled with that contained in the flask in which the experiment was made. Priestley thought the newly-discovered gas was air deprived of some combustible matter, and he therefore named it "dephlogisticated air;" it was named Oxygen by the French chemists on account of its producing acids, but it is not the universal acidifying principle, for many acids do not contain a trace of

this element. Discovered the action of plants upon vitiated air. Discovered the evolution of oxygen by aquatic plant growing in water containing carbonic acid; that the presence of light was necessary to this change; that in sunshine it was most rapid, and that it was in a great measure independent of warmth.

Ray discovered that several metals, when heated in air, increase in weight; this is due to their combination with oxygen; the results were formerly named "calces," under the idea that the metals changed into earth like lime or "calx;" these are now called "oxides."

Reaumur introduced 0 and 80 degrees to denote the freezing and boiling point of water; this scale is rarely used in England.

Roebuck devised the apparatus for producing sulphuric acid in large quantities at a cheap rate.

Romer and Bradley calculated the velocity of light at 192,000 miles in a second.

Rumford experimented upon the radiation of heat.

Rutherford first examined pure Nitrogen.

Santorio and Drebbel divide between them the honor of the discovery of the thermometer.

Saussure discovered the peculiar form of vesicular vapor of the mists on the Alps.

Scheele discovered chlorine. Ascertained that common air is a mixture of two distinct gaseous substances, one of which is capable of supporting combustion; this, accordingly, he called "empyreal air;" the other being neither capable of supporting combustion nor animal life, he called "foul air;" these are the Oxygen and Nitrogen of modern chemists. Demonstrated that silica and alumina are two perfectly distinct bodies; he likewise discovered that soda might be obtained from common salt. "First noticed the distinction between heated air and heat emanating in straight lines," or, in modern terms, the difference between convective currents

and radiation of heat: he says, represent to yourself a little hillock of burning coals; in this case, the heat darting from this hillock all around, is that which may be reflected by a metallic polished plate; that, on the contrary, which rises upwards and may be driven by winds to and fro unites with air. I call the first kind by way of distinction Radiant Heat."

SCHARDER analyzed the seeds of wheat, rye, barley, and oats, and ascertained the quantity of earthy matter which each contained, and made elaborate experiments upon the absorption or secretion of such matters by growing plants.

SEFSTRÖM discovered Vanadium.

SEGUIN experimented upon the transpiration of moisture from the human body.

SINGER gave the best and most explicit directions for ensuring personal safety during a thunder-storm.

SMEATON brought the air-pump to its present state of perfection.

SMITH, DR. C., proved the invaluable property of nitric acid vapor as a disinfectant.

STAHL invented the name "phlogiston," by which he denoted a common principle of combustible bodies; it is expunged from modern chemical nomenclature.

SMITHSON ascertained the form of hail-stones and snow-flakes.

STROMEYER discovered Cadmium.

TENNANT discovered Osmium. Made many useful applications of chemistry to agriculture. Probably discovered, certainly first made, chloride of lime or chlorinated lime, under the name of oxymuriate of lime, as a bleaching material.

TENNANT and DESCOTILS simultaneously discovered Iridium.

THOMSON constructed elaborate tables regarding the expansion of liquids by heat.

TORRICELLI discovered the Barometer.

TREVETHIC constructed the high-pressure steam-engine.

VAN HELMONT first employed the term "gas;" it is now used to denote all aëriform matters which are different in chemical constitution to the atmosphere, though resembling it in the physical property of permanent elasticity or power of resisting transition into the liquid or solid state by pressure or cold. He made the remarkable experiment concerning the growth of a willow tree in a limited quantity of earth, watered for several years with distilled water; the tree originally weighed five pounds; not fifty pounds as generally stated.

VAUQUELIN discovered Chromium.

WARD discovered the fact that plants would grow and flourish in a confined portion of air.

WATT proposed chlorine as a bleaching agent. Was probably the first philosopher who observed that moisture was deposited upon a cold surface when held over the flame of inflammable air, (hydrogen.) Made the first capital improvements upon the steam-engine, and it may be regarded as a machine upon which science and art have lavished their choicest resources.

WELLS, DR., discovered the physical cause of the beautiful natural phenomenon of dew.

WILLIAMS made the experiments upon the rupture of iron bomb-shells, when the water contained in them was frozen.

WÖHLER discovered Glucinum. Discovered Yttrium. Accurately demonstrated the nature of Alumina.

WOLLASTON discovered Palladium and Rhodium. Invented the "cryophorus."

WOOD made known Platinum in Europe.

WOODWARD experimented upon the transpiration of water by plants.

Acknowledgment of the quotations which occur throughout the Chemistry of The Four Seasons.

Page 34, Magazine of Popular Science; 37, Treatise on Heat, Society Diffusion of Useful Knowledge; 52, 53, 54, 55, Davy's Lectures on Agricultural Chemistry; 91, Mag. Pop. Sci.; 94, Priestley's Experiments on Air; 95, Sir J. Pringle's Discourse to the Royal Society; 99, 100, Brande's Manual of Chemistry; 107, 108, Davy's Lect. Ag. Chem.; 144, Introduction to Practical Organic Chemistry, anonymous; 153, Brande's Manual; 154, 155, Lardner's Cyclopedia; 157, Sir E. Home, Philosophical Transactions; 167, Lardner; 185, Arnott's Elements of Physics; 187, Forbes' Annals of Philosophy; 191, Davy's Salmonia; 192, Treatise on the Objects, Pleasures, and Advantages of Science; 210, Davy's Agricultural Chemistry; 213, Macculloch on Malaria; 233, 234, Brande's Manual; 237, Singer's Elements of Electricity; 237, Brande's Manual; 237, 2d quotation, Bacon's Novum Organon; 238, Franklin on Electricity; 254, Anonymous; 339, Chronicles of the Seasons; 343, Mitchell's Natural Philosophy; 344, Polytechnic Magazine; 349, Chronicles of the Seasons; 370, Arago; 417, Arnott; 425, Thomson; 435, Sedgwick.

THE END.